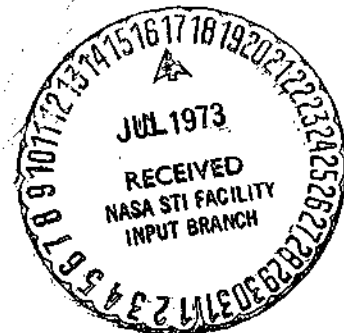


## FINAL REPORT

G3/34



Prepared For  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
JOHNSON SPACE CENTER  
HOUSTON, TEXAS

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APPLICABILITY OF LAND USE MODELS FOR THE  
HOUSTON AREA TEST SITE

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NAS 9-13081

29 June 1973

FINAL REPORT

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
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## PREFACE

This report documents the results of a study entitled "Survey, Study, and Documentation of Physical and Ecological Models Pertinent to the Houston Area Test Site (HATS)". The work was conducted for the NASA Johnson Space Center under Contract No. NAS 9-13081. After the publication of the Second Quarterly Progress Report, the work was redirected by JSC to concentrate upon land use models. The Appendices of the Second Quarterly Progress Report which document the general survey are republished in their entirety in this report. The material in the Appendices was prepared by Ed Sobak and Bill Piske who was then HATS Project Manager.

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## 1.0 INTRODUCTION AND SUMMARY

This report contains descriptions of land use models which were considered for their applicability to the Houston Area Test Site. These models are representative both of the prevailing theories of land use dynamics and of basic approaches to simulation. The models considered are:

- A Model of Metropolis<sup>1</sup> - Developed by Ira S. Lowry of the RAND Corporation for the Pittsburgh Regional Planning Association.
- Land Use Simulation Model<sup>2</sup> - Developed by Kenneth J. Schlager of the Southeastern Wisconsin Regional Planning Commission.
- Empiric Land Use Forecasting Model<sup>3</sup> - Developed by Traffic Research Corporation for the Commonwealth of Massachusetts.
- A Probabilistic Model for Residential Growth<sup>4</sup> - Developed by Stuart Chapin, Shirley Weiss and Thomas Donnelly of the University of North Carolina.
- The Regional Environmental Management Allocation Process (REMAP)<sup>5</sup> - Developed by Bernard J. Niemann, Jr. and Allen H. Miller of the University of Wisconsin, Environmental Awareness Center.

It should be noted that some of these models (especially the first three) have been adopted for use by other localities and have, in many cases, undergone extensive modifications. However, the set considered in this report does serve to illustrate the important basic concepts.

The following recommendations and conclusions have resulted from this study:

1. The REMAP approach to land use planning is the most easily implemented of the models using a physical attributes data base such as could be derived from remote sensing. REMAP is a non-predictive model; it attempts to state how land should be allocated for a particular purpose given a set of design goals. The importance of this type of program is magnified by recent Federal legislation requiring a review of alternatives for Federal laws and projects with respect to environmental impact.

2. As a first step in developing REMAP capabilities, the SYMAP program which is available at JSC can be used in conjunction with the HATS data base. Thematic maps of land use were generated under this study using SYMAP and a version of the HATS data base provided by JSC. Maps were also generated which displayed "recreational potential" in Harris County (using weighted linear combinations of land use attributes, similar to the approach of REMAP). The preliminary nature of the HATS data base provided to this study prevented the generation of maps of adequate accuracy (from the viewpoint of content). However, the feasibility was demonstrated; it is understood that an improved data base is now available.
3. Predictive models can play an important role in HATS if used in conjunction with other types of models such as hydrological models. The objective would be to obtain essentially parametric data on the effects of new plants, etc. on the distribution and size of residential communities. This data could then be used in conjunction with, for example, watershed models, to assess the effects of this growth on public safety (floods). The models would be used in a "what if?" mode to essentially highlight potential problems rather than necessarily accurately predicting urban growth. The assumption is that planners could tolerate a certain false alarm rate. The appendices of the Second Quarterly Report of this study have been included in this report as a guide to the potential for linking land use models with physical models.
4. The types of predictive models which have the most immediate, general potential for HATS are represented by the Lowery and Chapin, Weiss and Donnelly models. The EMPIRIC model is most adaptive to a region marked by stability and to situations in which the basic problem is reallocation of essentially the current population. This model requires an extensive amount of historical data. On both counts, this model would not appear to be appropriate for JSC use in HATS. The Schlager model is basically behavioristic relying primarily on an understanding of the local socio-economic structure and subjective assessments of behavior. This model

could possibly be adapted to very local conditions, e.g., the area in the immediate vicinity of JSC. The Chapin, Weiss and Donnelly model is behavioristic, but it would appear to be much more adaptable as a general research tool, since it aggregates the behavior of the developer, builder and buyer at a high level. The underlying theory of the Lowry model (gravitation with certain behavioristic elements) would appear to be very representative of the current growth in HATS.

The report first presents a perspective of the world of land use models and then presents summaries of the models under consideration.



## 2.0 A PERSPECTIVE OF LAND USE MODELING

Several excellent summaries of the state-of-the-art in land use models have been prepared. Those which have been useful in this study are the works of Kilbridge, O'Block and Teplitz<sup>6</sup>, Lowry<sup>7</sup>, Lamb<sup>8</sup> and King<sup>9</sup>. All of these works are attempts to provide a coherent framework for discussing land use models; a frame of reference is needed due to the wide diversity of such models. The purpose of this section is to present the considerations which enter into the discussion of the models selected for this study.

The Kilbridge, O'Block and Teplitz (K.O.T.) approach is perhaps the most general analysis of land use models. The K.O.T. framework clarifies the confusion which often results from the use of the terms "land use models" and "urban planning models". Urban planning models are taken to include:

- Land use
- Population
- Transportation
- Economic activity

It is shown that there are few models which can be considered "pure" with respect to any of these categories. In this report, the words "urban", "land", "use", "planning" and "model" will be used in a variety of combinations, in general, referring to the broad context of urban planning models used by K.O.T.

Another important clarification provided by K.O.T. is with respect to the function served by the model. The authors observe that models may be used to project land use, allocate land use or derive other parameters from land use. In this report, emphasis will be placed upon the projection and allocation functions.

Lowry is most concerned with analyzing models against the context of underlying theory. In Reference 7, seven models are analyzed to determine explicit and implicit statements of market forces underlying urban growth. The basic features of market models is determining such entities as the prices at which a developer will subdivide, at which a builder will offer and at which a buyer will accept. These models are also termed "rational choice" or "behavioristic" models.

At the opposite pole of land use theory are "gravity" models described in the following by Lowry<sup>1</sup>.

"The social physicists are interested in empirical laws of social interaction and mass behavior, rather than in reasoning from principles of individual behavior. The one that concerns us here is their finding that a variety of relationships among groups of actors (people, business enterprises) can be summarized by a simple analogue to Newton's law of gravity; the level of interaction is directly proportional to the . . . size of the group . . . and inversely proportional to the distance between them."

As noted by K.O.T.<sup>6</sup> another approach to classifying land use dynamics is through the use of trend models. Historical data can be gathered and through the use of regression techniques the mathematical relationships of a set of control variables to other measured parameters can be determined. These relationships can then be used with projected control variables (e.g., industrial expenditures for equipment) to determine (extrapolate) how the system will respond to the stimulus. Obviously, the validity of these techniques rests upon the general "stability" (conversely, the predictability) of the area under study.

There is yet another choice with respect to underlying theory; namely, dispense with concern for the predictive aspect of modeling and look for the normative solution (i.e., how should the land be used?). To summarize the approaches to model theory which will be used in this report there are

- Theory Based
  - Behavioristic
  - Gravity
  - Trend
- Normative

All of these types are included in the set of models discussed in this report.

Lamb's primary concern is with determining how the various models work and what is implied analytically by the structure of the models. He provides an introduction to the many mathematical techniques used in urban model development by giving simplified examples.

King provides a general description of how the theory based models are generally structured.

"In very crude form then, the problem involves . . . three components . . . There are the data inputs which involve the exogenously determined values and the data to be used in estimating the different parameters of the model. (This latter phrase is often referred to as the calibration of the model.) Then there is the model which performs the generation and allocation of the variables of interest . . . Finally, there are the outputs which are the predicted levels of development for each land-use activity and each subregion.

This is probably the reasonably expected structure. However, the importance of the data input aspects must be emphasized.

All of the theory based models must be driven by certain given conditions (the exogenous variables). The other important aspect of data highlighted by King's remarks is the role of data in calibrating the model. Obviously regression models depend heavily upon data to generate the requisite regression coefficients. However, behavioristic and gravity theory based models can require a considerable mass of basic operating data. Behavioristic models typically must be provided with data describing the makeup of the households (15% professional, 20% white collar industrial, 45% blue collar industrial, etc.), financial data, and age and family size distributions. This data is basically objective, but in addition, data must be provided which describes economic behavior (e.g., the type of dwelling which will be purchased by a blue collar worker making \$7000 a year with five children, two of whom are of college age). This tabular behavioral data can represent a sizeable data gathering effort.

Gravity models in their simplest form do not necessarily require a large data gathering activity beyond describing current land use. However, as implemented in more sophisticated models gravity models generally tend toward a hybrid situation introducing decision concepts in the model. Thus, in the example of a gravity oriented model used in this study, A Model of Metropolis, a considerable calibration data gathering activity (traffic counts and home interviews) was undertaken to generate empirical curves relating frequency of trips to miles traveled.

The only class of models reviewed in this study which could be driven essentially by an "uncooperative" data base is the normative model category. A data base is uncooperative in the sense that it can, if required, be developed strictly from observation and generally available information. Obviously the extreme case of such a data base is one derived from remote sensing. A more involved structure could include information obtained from land use maps, soil survey maps, etc. and accepted engineering guidelines (e.g., cost to excavate soil of a given type).

Another distinguishing characteristic among land use models is the type of linkages which are present. The basic element of most models is a square area of a standard size, i.e., a region is subdivided into gridded cells. In some models, it is necessary to keep track of simulation variables as a function of time. These temporal linkages impact the model design in the "bookkeeping" aspects. It may also be necessary to relate information in one cell to information in another cell. Accommodating these spatial linkages is straightforward from a program design viewpoint, but the logic can become rather complex and computational speed can be sacrificed for the necessary search procedures. To circumvent spatial linkages some models will include, in the descriptions of cells, such items as "distance to nearest school" or "distance to shopping center" rather than searching the data base to find a cell which contains a school and which is nearest for all concerned.

The objective in using a land use model can strongly influence the design of a model. Aggregation with respect to both space and time is an important point of departure for the model builder. Examples will clarify the aggregation issue. Determination of the population of a city or the required square footage of multiple unit dwellings in 1990 has considerably different design implications than those associated with determining where various culture classes and where the dwellings will be located. Determining the ultimate impact of a new industry on housing requirements is far different than stating how this growth (in time) will occur.

The final distinguishing characteristic which will be considered in this report is the basic model philosophy. As in most modeling situations, the models can be characterized as either deterministic or stochastic. At

the risk of making a gross oversimplification, deterministic models are concerned with the output of a model for a given set of input; stochastic models are concerned with the statistics of the ensemble of outputs associated with a collection of sets of input data. The statistics of the input data elements hopefully describe the frequency distributions encountered in the real world. In addition to concern for randomness in inputs and randomness in outputs, stochastic models can consider randomness is the reaction of model subelements to stimulus.

Two basic alternatives exist for accomodating stochastic modeling -- Markov process formulation and Monte Carlo simulation. Modeling with a Markov process requires laying out of the system as a sequential process and identifying the transitions which may occur from step to step and quantifying the transitions as a probability of occurrence. Thus, the model may start with a bare piece of land. At an instant of time, this land could remain barren, be converted to agriculture, be converted to housing, etc., at varying levels of probability. Assuming that the land transits to housing then at varying levels of probabilities it can be used for various classes of housing. The process can be continued to a desired time. These models result in development of "probability trees"; such a model was constructed to describe the deterioration of housing in the San Francisco area. An aside is perhaps in order here. As modeling techniques are applied to a new area, Markov processes are a valuable tool in developing an understanding of the critical aspects of the system being modeled. As work with the system continues, more explicit modeling techniques are applied. This has been true in spacecraft guidance studies, aircraft corridor maintenance models and missile range safety system studies; it appears to be the case for land use modeling.

A more prevalent approach to land use models which consider stochastic processes is the use of Monte Carlo techniques. King notes that "... Monte Carlo models represent an essentially low level approach to the study of probabilistic systems, and again there are other land use studies . . . that develop more formal stochastic models of land use processes". This statement obviously places a mathematically rigorous description of a system above an explicit statement of how the system will behave. Actually, the primary concern of Monte Carlo approaches is to circumvent as much as

possible the myriad of assumptions and simplifications which normally must be made in fitting the more "elegant" descriptions to a complicated process.

Before closing this section, it should be noted that nothing has been said concerning the use of differential equations in land use modeling. King's observations on this issue coupled with the lack of employing such equations in land use models will suffice.

"The classical approach to mathematical prediction, at least in the physical sciences, has been to structure a set of differential equations . . . In the social sciences, differential equations have been used in studying phenomena such as population growth and changes in different economic variables, and it is perhaps not surprising that attempts have been made to structure differential equations for the prediction of urban land use levels. The best documented attempt along these lines was the work done on the POLIMETRIC model in Boston.

This model . . . has since been discarded by the Boston group.

The model appears to have been discarded largely because of problems inherent in the data requirements."

The data requirement bottleneck in this instance, resulted from the fact that POLIMETRIC attempted to account for all movements among the cells of the study area. King also points out that land use models are predominantly linear; again the example given of a nonlinear model is POLIMETRIC.

The advice of Alonso, on model building stemming from an analysis of the quality of empirical data on which most theory based models justifies the sometime simplified mathematical structures found in land use models.

- Avoid intercorrelated variable
- Add where possible
- If addition is not possible, add or divide
- Avoid, as far as possible, taking differences or raising variables to powers
- Avoid, as far as possible, models which proceed by chains.

The preceding remarks suggest the following questions to be answered with respect to any model of land use.

1. What is scope of the model?

2. What function is served by the model?
3. What is the theory upon which the model is based?
4. What is the modeling philosophy?
5. What general mathematical technique is employed in the model?
6. What is the basic organization of the model?
7. What is assumed to be given by the model (exogenous inputs)?
8. What are the characteristics of the data base used by the model?
9. What is aggregated?

These questions will be addressed in the following section for each of the models under consideration.

### 3.0 THE MODELS

This section contains discussions of the models selected for detailed review. The objective was to select a group which would be representative of the range of considerations presented in the previous section. Certain of the models have been refined and adapted for applications outside the original region for which they were developed. However, the versions presented here serve to illustrate most of the basic concepts. There is no attempt to develop a uniform level of documentation in this section; the documentation presented here reflects the level of description available in the reference material. The emphasis is upon program concepts. Program flow documentation is available for some models, but, in general, the specific program structures could not be adapted directly for HATS so such documentation would be superfluous here. In some instances, it has been appropriate to select portions of the original documentation or summary material; where this has been done the reference has been acknowledged.

#### A Model of Metropolis (The Lowry Model)

The Lowry Model was developed for the Pittsburgh Regional Planning Commission and was intended to "generate estimates of retail employment, residential population and land use for sub-areas of a bounded region". The model allocates space and is predictive in the sense that the time at which the estimate is provided is when equilibrium conditions are achieved; however, no statement is made as to when this situation will occur. The model set out to be primarily a gravity model; however behavioristic considerations drive certain parameters of the model so in a sense it is not purely gravitational. The model is based upon a detailed analysis conducted in the Pittsburgh area of the frequency of work trips and shopping trips as a function of the distance traveled. The work trip information is used in conjunction with given locations of industries to distribute the work force residential units. This is accomplished through first computing the attractiveness of each tract in the study region based upon distance to the various places of employment. Retail stores are then located in a similar fashion based on shopping-trip data; the model then iterates until certain constraints are satisfied. Accounting for the use of various tracts is accomplished, but with considerable aggregation. The assigned categories



are at a very high level (e.g., residential, retail, industrial). The data base used for this study was the trip information which was obtained from a detailed traffic study. Accounting of all the land area must be made for the categories of

- Unusable land
- Business, industrial and administrative establishments
- Retail establishments
- Households

The following description of the Lowry model and the associated computations are taken from Lamb.

This model is composed of a system of twelve equations, with three of these equations acting as constraints or limiting factors. Reading the equations will not be difficult if one uses the following interpretive technique. The letter A always represents area of land, it may be modified with the use of a superscript such as B, referring to the basic sector, and it may be further modified with a subscript such as j, referring to a specific tract. Thus, the symbol  $A_j^B$  means the area of land used by the basic sector, in tract j.

Another example,  $E^R = \sum_{j=1}^n E_j^R$  is interpreted as such: the employment in the retail and service sector for the region ( $E^R$ ) equals the summation  $\left( \sum_{j=1}^n \right)$  of the employment in the retail and service sector in all of the tracts ( $E_j^R$ ). The subscript j represents the number of a specific tract. The mathematical notations used in the equations of this model are as follows:

<u>Symbol</u>	<u>Represents</u>	<u>Measurement Unit</u>
A	Area of land	1,000 sq. ft.
E	Employment	persons
N	Number of resident households (population)	household
T	Trip distribution index	
Z	Constraint	

The following superscripts and subscripts are used to modify the meaning of the above symbols:

- U = Unusable (land)
- B = Basic sector
- R = Retail and service sector
- H = Household sector
- k = class of establishments within the retail sector; also defines related class of "shopping" trips
- m = number of classes of retail establishments ( $k=1, \dots, m$ )
- i, j = subareas of a bounded region, called tracts
- n = number of tracts ( $i=1, \dots, n$ ;  $j=1, \dots, n$ )

Unspecified functions and coefficients are represented by lower-case letters: a, b, c, d, e, f, g.

For each of the tracts the total amount of land available and the total amount of land that is not usable by any of the activities which are to be allocated must be known and provided as exogenous inputs to the model. The remainder of the land in each tract is presumed to be available for use by the basic establishments, by retail and service establishments and households. This is represented in the following mathematical statement.

$$(1) \quad A_j = A_j^U + A_j^B + A_j^R + A_j^H$$

For each tract, the model requires that the quantity of land used by basic establishments and employment opportunities be provided exogenously to the model. Referring to Equation 1, it will be noted that three of the five variables are given or supplied as exogenous inputs. ( $A_j$  represents the total land in the tract;  $A_j^U$  represents the total amount of land in the tract unavailable for development; and  $A_j^B$  represents the quantity of land that is used by the basic industrial sector.) Thus, each tract within the region is viewed as having four types of land within it: land that is unusable for future development; land that is used by the basic sector; land that is to be used by retail and service establishments; and land that is available for household utilization. Summing the four numbers, total area in the tract should be obtained. At this point it may be seen that there are essentially two unknowns in the previously stated equation: the

land that is available for retail and service establishments and the land that is available for households. These items may be added together and termed the residual land. Table 1 presents the land use data base for the Lowry model.

Table 1. Land Uses

- Services
  - Offices - Central
- Heavy Commercial
  - Wholesalers and Distributors
  - Junk and Salvage Yards
  - Vacant Commercial
  - Other Heavy Commercial
- Manufacturing
  - Primary Metals
  - Vacant Manufacturing
  - Other Manufacturing
- Utilities and Communication
  - Utilities - Communication
  - Trucking Terminals and Warehouses
  - Railroad Stations and Bus Depots
  - Vacant
  - Other
- Public Buildings
  - (Part) County Farm and Bureau of Mines
  - (Part) Colleges and Custodial
  - Hospitals and Sanitaria
  - Military Installations
  - Vacant
  - Other
- Public Open Space
  - Stadiums, Drive-in Theaters,
  - Race Tracks
  - Golf Courses
  - Parks, Beaches
  - Cemeteries
  - Other
- Unusable Land
  - Water or Swamp Areas
  - Mines and Quarries
  - Slope > 25%

In the Pittsburgh application of the model, retail and service establishments were divided into three groups each with a characteristic market area, minimum number of employees, and household support ratio. The three groupings (indicated with a  $k$  superscript in the equations,  $k$  being 1, 2, or 3) used were derived from available data and are as follows:

k	GROUP	$z^k$	HOUSEHOLD REQUIRED PER EMPLOYEE	MARKET WEIGHTS	
		MINIMUM EMPLOYMENT		$c^k$ Household	$d^k$ Employee
1	Neighborhood facilities	30	9.4	.90	.10
2	Local facilities	200	5.5	.70	.30
3	Regional facilities	20,000	8.3	.50	.50

Using the above information, Equation 2 states that the number of retail and service employees within the region, by type of facility, is equal to some portion of the total number of households in the region.

$$(2) \quad E^k = a^k N$$

With the regional employment in the retail and service sectors determined in Equation 2, the distribution of this employment to tracts is recognized as being a function of customers and travel of the customers to the facility. The customers are separated into two groups: those shoppers coming from the household to market and those shoppers coming from a place of employment in the same tract. It is further recognized that households and employees represent different portions of sales depending upon the type of retail and service facility. These concepts are represented in Equation 3 as follows. In a zone, the retail and service employment for each facility group ( $E_j^k$ ) is equal to a portion ( $c^k$ ) of the tracts' households ( $N_i$ ) as decreased with the increased travel index ( $T_{ij}^k$ ) plus a portion ( $d^k$ ) of employees ( $E_j$ ) within the tract. The  $b^k$  term adjusts the employment in each tract so that the sum of the tracts' employment equals the region's employment. This term, ( $b^k$ ) is determined in Equation 4.

$$(3) \quad E_j^k = \left[ \sum_{i=1}^n \left( \frac{c^k N_i}{T_{ij}^k} \right) + d^k E_j \right] b^k$$

$$(4) \quad b^k = E^k / \left( \sum_{j=1}^n E_j^k \right)$$

The value of  $b^k$  is then used in Equation 3 to adjust the values of each  $E_j^k$  (decrease if the sum of  $E_j^k$  is greater than  $E^k$ , and increase if the sum of  $E_j^k$  is less than  $E^k$ ).

Total employment in the tract ( $E_j$ ), then, is equal to the sum of basic employment plus the retail and services employment. Stated in equation form it is:

$$(5) \quad E_j = E_j^B + \sum_{k=1}^m E_j^k$$

Using a ratio ( $e^k$ ) of land used per type of retail employee, determined exogenously, the quantity of land used by retail and service facilities is determined as follows:

$$(6) \quad A_j^R = \sum_{k=1}^m e^k E_j^k$$

Thus, having determined  $A_j^R$  (land used by retail and service facilities in tract  $j$ ) the quantity  $A_j^H$  is the only variable in Equation 1 without a value. By rearranging Equation 1 this value may now be calculated for each tract.

$$A_j^H = A_j - (A_j^U + A_j^B + A_j^R)$$

The region's population (measured in households) is regarded as a function of total employment (Equation 7) and the number of households in each tract is a function of that tract's accessibility to employment opportunities (Equation 8):

$$(7) \quad N = f \sum_{j=1}^n E_j$$

$$(8) \quad N_j = g \sum_{i=1}^n \frac{E_i}{T_{ij}}$$

The term  $g$  in Equation 8 is an adjusting factor computed with Equation 9 which adjusts each tract's population so that the sum of all population for these tracts equals the region's population.

$$(9) \quad g = N / \left( \sum_{j=1}^n N_j \right)$$

### Constraints

The above nine equations represent the formulation of the model operation. However, the model must have limits applied to certain terms so that the formula generates only rational quantities. The three constraints used in this model are as follows:

1. The establishment of a retail and service facility must meet the minimum number of employees ( $Z^k$ ) before it can come into existence. This is expressed mathematically in Equation 10.

$$(10) \quad E_j^k \geq Z^k, \text{ or else } E_j^k = 0$$

2. Also, the quantity of land to be used by the retail and service facilities must be available within the tract. This constraint is structured so that only the unusable land and basic sector are of a higher priority in consuming the tract's land. This constraint is expressed in Equation 11.

$$(11) \quad A_j^R \leq A_j - (A_j^U + A_j^B)$$

3. The third and final constraint used in the model limits the population to a maximum density. This value was determined from the study data base, and never found to exceed 1.5 households per 1,000 sq. ft. of residential land. In equation form, this constraint is shown in Equation 12.

$$(12) \quad N_j \leq Z_j^H * A_j^H$$

The solution of the nine basic equations, as constrained by population density, available land, and minimum retail and service facility size, represents an equilibrium distribution of retail activities and an associated equilibrium distribution of residential population.

The solution of this model proceeds in the following general manner:

1. Approximate distribution of households based on basic sector employment and transportation
2. Approximate distribution of retail and service facilities
3. Compare results with constraints
4. Determine final distributions and convert to land consumed

The specific mathematical sequence used in finding a solution to the set of equations is as follows.

#### Step One

The technique best adapted to machine computation is an iterative method, beginning with Equations 1, 7, 8, and 9. As a first approximation, assign the exogenously-determined value of  $E_i^B$  to the variable  $E_i$  (or  $E_j$ ), and set  $A_j^R = 0$ . These four equations can then be partitioned from the rest of the system and solved for  $g$ ,  $N_j$ , and  $N$  by an inner iteration. First, obtain a value for  $A_j^H$  from Equation 1.

$$(1.1) \quad A_j^H = A_j - A_j^U - A_j^B - A_j^R$$

The value of  $N$  is then established in Equation 7.

$$(7.1) \quad N = f \sum_{j=1}^n E_j$$

Or, in order to speed convergence, anticipate the final value of  $N$  by allowing for the labor-force requirements of retail establishments as well; where  $E^B$  represents all basic employment:

$$(7.2) \quad N = f \frac{E^B}{1 - f \sum_{i=1}^m a_i^k}$$

This short cut would not be appropriate in all contexts. Then compute population potentials.

$$(8.1) \quad \frac{1}{N_j} = \frac{n}{\sum_{i=1}^n} \frac{E_i}{T_{ij}}$$

The value of the scale factor (g) is determined by reference to the total population to be allocated as follows:

$$\frac{1}{g} = \frac{N}{\sum_{j=1}^n \frac{1}{N_j}}$$

This scale factor is used to reduce the population potentials to a second approximation:

$$(8.2) \quad \frac{2}{N_j} = \frac{1}{g} \frac{1}{N_j}$$

The left-hand term is then tested against the maximum-density constraint ( $Z_j^H$ ) for all cases in which:

$$\frac{2}{N_j} \geq Z_j^H A_j^H,$$

$$\frac{3}{N_j} = Z_j^H A_j^H.$$

The excess population of tract j (i.e.,  $\frac{2}{N_j} - \frac{3}{N_j}$ ) is distributed among all other tracts in proportion to their population potentials by revising the scale factor once more.<sup>1</sup>

For all other cases,  $\frac{3}{N_j} = \frac{2}{g} \frac{2}{N_j}$ , and we close the system with:

$$(9.1) \quad N = \sum_{i=1}^n \frac{3}{N_j}$$

---

<sup>1</sup> Lowry experimented with an alternative to this method: distributing the excess population of tract j among the eight adjacent tracts in proportion to their available capacity. The method described above, however, gives better empirical results and is much more stable in the context of successive iterations.



### Step Two

Now partition Equations 2, 3, and 4, and again solve by repeated approximations. The solution of Step One gives values for  $N$  and  $N_j$ , which are now fed into Equations 2 and 3, respectively. Once more, use the exogenous  $E_j^B$  as a first approximation for  $E_j$  in Equation 3. Then calculate employment potentials in retail trade  $k$  for each tract as follows:

$$(3.1) \quad E_j^k = \sum_{i=1}^n \left( \frac{c^k N_i}{T_{ij}^k} \right) + d^k E_j$$

These potentials are rescaled so that they equal the total employment determined in Equation 2.

$$(2.1) \quad E^k = a^k N$$

$$(3.2) \quad E_j^k = b^k E_j^k,$$

where

$$b^k = \frac{E^k}{\sum_{j=1}^n E_j^k}$$

This provisional solution is then tested against the minimum size constraint. Using search routine to locate the smallest  $E_j^k$ , set it equal to zero, and rescale (increase) employment in all other tracts. This process<sup>2</sup> is repeated until there are no instances in which  $E_j^k$  is less than  $Z^k$ , and Equation 4 is satisfied.

$$(4.1) \quad E^k = \sum_{j=1}^n E_j^k$$

### Step Three

When Step Two has been completed for each of the three retail trades, Equation 5 and 6 may be solved by substitution. The retail-land variable ( $A_j^R$ ) generated by Equation 6 is then tested against the amount of space

<sup>2</sup>Where  $Z^k$  is large, a more efficient method is to zero  $E_j^k$  in batches (e.g., all values below .01  $Z^k$ ; all values below .02  $Z^k$ ; etc.) rather than one tract at a time. Both methods have been used at various stages in the development of the model.

actually available in each tract; i.e., where  $A_j^R > A_j - A_j^U - A_j^B$ , we set  $A_j^R = A_j - A_j^U - A_j^B$ . In other words, if there is not enough space to accommodate retail employment at average densities, overcrowding occurs. Note that retail uses still have priority over residential uses. If population has been allocated to such a tract by Step One, it will be removed by the residential-density constraint on the next pass.

The values of  $E_j$  yielded by Equation 5 will be equal to or greater than the assumed  $E_j$  used in the first trial of Equation 8, and the same is true of the values of  $A_j^R$  yielded in Equation 6. The solution method thus slowly feeds in retail employment and land use as determinants of population distribution. These new values,  $E_j$  and  $A_j^R$ , are returned to the system composed of Equations 1, 7, 8 and 9 and a second iteration of the entire model is begun. Continue in this fashion until the iterations converge on a stable set of values for all the variables.

#### Land Use Simulation Model

This model is a good example of the "what if?" application of land use models referred to in the previous section. The model was designed to test the effectiveness of land use plans. It is assumed that the amount of given data includes

- Zoning and subdivision regulation
- Freeways and street locations
- Open space reservation
- Employment levels

The development and building community are then presumed to compete for available land and households will select from the then available housing. The model is based almost entirely on a behavioristic theory. The model is highly spatially aggregated; it analyzes the demand and supply functions for types of lots and does not attempt to "map" land use. The model is essentially a sequence of algebraic functions which express availability of land and the demand created by the housing market. The sequence of events is as follows:

1. Allocate available land to all non-industrial uses.
2. Update the land use files to account for (1).

3. Allocate land to industry, retail stores, and schools and local streets.
4. Update the land use files.
5. Allocate land to residential and associated service uses.
6. Update files.

Agricultural lands are treated as residual lands which can be converted to any of the other uses. In its original version, this model treated industrial employment as an exogenous input. Spatial linkages are implied since in certain of the decision processes which are modeled attractiveness functions are calculated between the possible combination of zones. The model requires an analysis of regional household data. This requires matching of household characteristics such as age, family income, family size and education with housing characteristics such as structure type, market value and ownership or rent status.

The model proceeds according to the steps outlined earlier. Three primary decisions are modeled

- The decision of the land developer to subdivide the land for residential use.
- The decision of the building contractor to build residential buildings.
- The decision of a household to rent or purchase a dwelling unit.

These decisions are modeled according to the following paragraphs.

The decision of the land developer to subdivide consists of two sub-decisions.

- Lot quantity subdecision
- Site location subdecision

The lot quantity subdecision is given by

$$RLDX = PHCC + (VACD - VACL)/TLIA$$

where

RLDX - base land development rate (lots/month)

PHCC - projected lot sales based on housing constructed (lots/month)

VACD - lot vacancies, desired (lots)

VACL - lot vacancies, actual (lots)

VACD = (PHCC) (VACR)

VACL = RLD - HC

where

RLD - residential land developed (units)

VACR - vacancy ratio (months)

HC - total housing units

The model allows a zoning limit to be imposed and is structured to prevent the land development rate from becoming negative, although Schlager points out that a negative development rate occurs if unsold developed lots revert back to raw land. The model accomodates the fact that land development takes place over time and even considers the delay time between start and completion of development. The inventory of available lots is adjusted in the model at discrete points in time.

The land developer's site location subdecision is more complex. At the time of the publication of Reference 2, two submodels were under evaluation.

The first approach modeled the site location process totally as a demand phenomenon. This demand was calculated as a function of the householder's decision to purchase.

The second approach considered the demand for the entire area under study, thus treating demand as the source for the quantity of lots, but not the location. This submodel considered the soil types of the region under study (which influence development costs) and the improvements needed for the various parcels of land. The model minimizes the total costs of the land developer in meeting the demand subject to zoning restrictions. Land is allocated using the following linear programming algorithm. Minimize

$$C_t = \sum_{m=1}^m \sum_{n=1}^n C_{rmn} R_{mn}$$

subject to

$$\sum_{m=1}^m \sum_{n=1}^n R_{mn} + SR_{mn} = R_d + SR_d$$

where

- $C_t$  - total private land development costs (dollars)
- $C_{mn}$  - cost of developing a lot of type m in zone n (dollars/lot)
- $R_{mn}$  - lots of lot type m in zone n (lots)
- $S$  - service lot ratio (retail, school, streets, etc.) required to support residential development
- $R_d$  - total residential land demand (lots).

It should be noted again that the demand is developed for the entire region. The second formulation above considers the generally prevalent condition, i.e., the developers with greater capital and more knowledge of the land market largely determine where residential areas will be located.

The decision of the buyer to buy, as modeled, involves three sub-decisions

- The decision to move
- The selection of a basic housing unit type package
- The selection of a particular site location

The decision to move is modeled simply as

$$HDXX(Y) = TO(XX) * HXX(Y)$$

where

- $HDXX(Y)$  - households of type XX departing zone Y
- $TO(XX)$  - turnover rate, household type XX
- $HXX(Y)$  - households of type XX in zone Y

The household type classifications used by this model are shown in Table 2.

The model considers the selection of a basic housing unit type as dependent on what is available. This is in turn dependent upon the subdivider's and builder's decisions. The housing unit types are shown in Table 3.

TABLE 2  
 LAND USE SIMULATION MODEL HOUSEHOLD TYPE CLASSIFICATION

Household Types					
Type	Education*	Occupation*	Income*	Age*	Sex-Race
1	College	White Collar	\$ 0 - \$ 8,000	Under 35	Male-White
2	College	White Collar	0 - 8,000	Over 35	Male-White
3	College	White Collar	8,000 - 12,000	All	Male-White
4	College	White Collar	12,000 - 20,000	All	Male-White
5	Non-College	White Collar	0 - 4,000	All	Male-White
6	Non-College	White Collar	4,000 - 8,000	Under 35	Male-White
7	Non-College	White Collar	4,000 - 8,000	Over 35	Male-White
8	Non-College	White Collar	8,000 - 12,000	All	Male-White
9	Non-College		12,000 - 20,000	All	Male-White
10		Blue Collar	0 - 4,000	All	Male-White
11		Blue Collar	4,000 - 8,000	Under 35	Male-White
12		Blue Collar	4,000 - 8,000	Over 35	Male-White
13		Blue Collar	8,000 - 16,000	Under 35	Male-White
14		Blue Collar	8,000 - 16,000	Over 35	Male-White
15	All	All	All	All	Female-White
16	Miscellaneous				Female/ Non-White

\*All household type characteristics are based on the head of the household.

TABLE 3  
 LAND USE SIMULATION MODEL HOUSING UNIT TYPE CLASSIFICATION

Type	Structure	Status	Market Value
1	Single Family	Own	\$ 0 - \$10,000
2	Single Family	Own	10,000 - 15,000
2	Single Family	Rent	0 - 60/mo.
3	Single Family	Own	15,000 - 20,000
3	Single Family	Rent	60 - 100/mo.
4	Single Family	Own	20,000 - 25,000
4	Single Family	Rent	100 - 150/mo.
5	Single Family	Own	25,000 & Over
5	Single Family	Rent	Over 150/mo.
6	2-3-4 Family	Own	0 - 15,000
6	2-3-4 Family	Rent	0 - 60/mo.
7	2-3-4 Family	Own	15,000 - 25,000
7	2-3-4 Family	Rent	60 - 100/mo.
8	2-3-4 Family	Own	25,000 & Over
8	2-3-4 Family	Rent	100 - 150/mo.
9	5-19 Family	Rent	60 - 150/mo.
10	Miscellaneous		

The selection of a particular site subdecision is dependent upon accessibility to employment, population and shopping. The travel time from a particular zone to all other zones is calculated and the relative attractiveness of all the other zones is calculated in terms of their total employment (employment accessibility), population (social accessibility), and retail employees (commercial accessibility).

The builder's decision to build is formulated in a manner very similar to the subdivider's decision. The model accomodates custom and speculative builders.

In its simplest form, the model considers the industrial locations as given and the allocation of service entities is accomplished by using simple ratios.

#### EMPIRIC

The EMPIRIC model was developed for the Boston Regional Planning Project to determine the effect of population changes and changes in public services and transportation networks upon population and employment in the various subdivisions of the region. The model is a trend model, relying heavily upon multiple regression techniques. The model proceeds according to the following steps (taken from Reference 3).

1. The land use model is calibrated (i.e., the equations are structured and the coefficients estimated) using data from two historical time points; say, time "t" and time "t+x," where time "t" is "x" years earlier than time "t+x". (The "x" year forecasting interval would normally be about ten years.)
2. The traffic prediction model is calibrated for the year "t+x".
3. Estimates of regional growth for an "x" year period are made for each activity to be predicted, and regional forecasts of these activities are made for time "t+2x".

4. The proposed transportation system is specified for the forecast year "t+2x". Also specified are forecast year characteristics of other policy variables to be used, such as public utilities service.
5. The land use model is applied to produce an "x" year forecast of subregional values of socio-economic and other land use activities at time "t+2x". The input data required for forecasting would include base year (time "t+x") values of activity levels, and base year and forecast year (time "t+2x") values of transportation system characteristics (such as travel times) and other policy variables.
6. The traffic model is applied to forecast for time "t+2x", traffic flows, times and costs, based on the land use pattern forecast in step (5) and on the proposed transportation system for time "t+2x".
7. The procedure outlined in steps (4) through (6) is repeated if the travel times and costs output from (6) differ substantially from final year values used in (5).
8. The procedures outlined in steps (3) through (7) are repeated for successive "x" year periods (i.e., to "t+3x", etc.), using activity levels and transportation system characteristics estimated by the land use and traffic models at the end of each period as starting levels for forecasting the next period. This step is continued until the final target year has been reached.

The EMPIRIC model is made up of a system of linear equations for which coefficients of all equations are estimated by simultaneous multiple regression analysis. The model is calibrated by measuring the levels of and changes in all pertinent activities over one or more time periods. The basic overall concept of the model may be stated mathematically by means of the following equation:

$$\sum_{j=1}^N a_{ij} R_{jh} (\Delta) + \sum_{k=1}^N b_{ik} R_{kh} (t-1) + \sum_{k=N+1}^M b_{ik} Z_{kh} = 0$$



where

$h$  = one of the subregions or zones comprising the study region  
= 1, 2, ...,  $H$

$i$  = one of the (output) activities to be forecast = 1, 2, ...,  $j$ ,  
...,  $N$

$k$  = one of the variables whose locations and intensities are  
related to development patterns of the forecast (output)  
activities in a causal manner = 1, 2, ...,  $N$ , ...,  $M$

$R_{jh}(\Delta)$  = the change in the output variable  $j$  in zone  $h$  from the  
beginning to the end of a forecast interval

$R_{kh}(t-1)$  = the value of the causal variable  $k$ (= output variable  $j$ )  
in zone  $h$  at the beginning of a forecast interval

$Z_{kh}$  = the value of the causal variable  $k$  in zone  $h$

$a_{ij}$  and  $b_{ik}$  = coefficients ( $a_{ij} = 1$  when  $i = j$ )

This equation thus relates the growth of a single output (dependent) variable  $i$  in zone  $h$  to: the growth of the other output variables  $j$  in zone  $h$ ; the present amount of the output variable  $i$  in zone  $h$ ; and the amount of the causal variables  $k$  in zone  $h$ .

The coefficients  $a_{ij}$  express the influence of the growths of dependent variables  $j$  ( $j \neq i$ ) on the desirability of zone  $h$  for dependent variable  $i$ . The coefficients  $b_{ik}$  express the influence of independent variables  $k$  on the desirability of zone  $h$  for dependent variable  $i$ . The realism of the equation and hence, of the entire model depends on whether it is possible to determine values of  $a_{ij}$  and  $b_{ik}$  which describe effectively the interrelationships between all activities.

The coefficients  $a_{ij}$  and  $b_{ik}$  are estimated (i.e., the model is calibrated) by means of simultaneous multiple linear regression analysis carried out on data from two time points in the recent past. There are  $N \times N$  values of the  $a_{ij}$  coefficients and  $N \times M$  values of the  $b_{ik}$  coefficients to be estimated; or, a total of  $N(N + M)$  coefficients. All  $a_{ij}$ 's having  $i=j$  are set equal to unity, and, for proper identification of the equation system, at least  $(N-1)$  of the  $a_{ij}$ 's and  $b_{ik}$ 's in each equation must be constrained (usually set equal to zero). (The inclusion of all or nearly all of the independent variables in each equation would lead to major problems of

coefficient instability, but theoretical analysis shows a sufficient number of the  $b_{ik}$ 's to be insignificant in the equations. Consequently, no identification problems are normally encountered.)

Once the model has been calibrated, it is operated in a recursive manner for forecasting purposes. This is one equation for each of the dependent variables in each zone, and the system of equations is solved separately for each zone. At full utilization, therefore, the model comprises  $N$  equations per zone of the form outlined above, whose simultaneous solution for a given forecasting interval will provide growths of zonal activity levels during this interval.

A Probabilistic Model for Residential Growth (The Chapin, Weiss and Donnelly (C.W.D.)

The Chapin, Weiss and Donnelly (C.W.D.) model allocates land for residential growth. The model is basically behavioristic in theory. The model calculates rather simple algebraic functions to assess the attractiveness of each cell in the study area for development as residential property. These attractiveness measures are then used against the backdrop of consumer demand to determine whether or not a particular parcel is developed according to the following steps (taken from Reference 4).

1. The computer inputs the inventory of subdivided and vacant land that will be available for new residential growth during the prediction period. Criteria determining which and how much land will be available are selected by the model user, as are the units in which available land is specified.
2. For each unit of land suitable for residential development, a measure of relative attractiveness is assigned. Assessed values are used to establish an initial attractiveness measure, which is combined with priming factor measures (i.e., how close the land is to major streets, etc.), and multiplied by the number of units available for growth in the land unit.
3. With the number of units of growth to be allocated specified as an input, a probabilistic method, based on the relative attractiveness of land units and on random number generation and sampling, is used to predict the location of new residential

growth. When a unit of growth is allocated to a land unit, the land's attractiveness is reassessed, since it then has less area available for growth. Growth is allocated first to subdivided land, and then to vacant land if the supply of subdivided land is not sufficient for the amount of growth to be allocated.

4. The allocation procedure is for a specified time period and can be repeated, either for the same period or for a succeeding period. For any one period the predicted growth can be determined as the average of repetition results, as a range of possible outcomes, or as the "best" run through statistical evaluative procedures. In long-range predictions, involving successive runs, the outputs of one run (such as reassessed attractiveness and available land remaining) may be used as inputs for the following run.

#### The Regional Environmental Management Allocation Process (REMAP)

REMAP was developed at the Environmental Awareness Center of the University of Wisconsin as a means of introducing a broad range of ecological considerations into planning public works. The program provides alternative allocations of land based upon a prescribed weighting of development factors. When used to evaluate highway routes REMAP can either "score" a proposed route, or it can be used to select a route using a dynamic programming algorithm. The model uses a data base which essentially consists of a comprehensive physical description of the study area. The data base is organized as follows:

- Landscape Units

- Natural Units

- Watersheds

- Cultural Units

- Study Area

- Counties

- Townships

- Corporate Limits

- Extra-Territorial Limits

Landscape Units (Continued)

Natural Characteristics

Hydrologic System

Watershed Order

Intermittent Streams

Streams

Minor Rivers

Major Rivers

Ponds

Lake < 50 acres

Lake

Fish Habitat

Climatological System

Mean Annual Snowfall

Greatest Daily Precipitation

Number of Days 90°F or Greater

Number of Days 32°F or Less

Ecologic System

Upland Hardwoods

Hardwoods with Hemlock

Hardwoods with Conifers

White Pine

Popple with White Birch

Oak Hickory

Pin Cherry

Norway Pine

Birch

Swamp Hardwoods

White Cedar

Tamarack

Black Spruce

Balsam

Shrub Carr

Marsh

Red Cedar

Landscape Units (Continued)

Physiographic System

Centroid Elevation

Center East Elevation

Center South Elevation

Center West Elevation

Center North Elevation

0-2% Slope

3-6% Slope

7-12% Slope

13-20% Slope

21% and Greater

Pedologic System

Soil Association

Escarpment

Esker

Drumlin

● Cultural Characteristics

Residential System

Residential-Rural

Residential-Recreation

Residential-Suburban

Residential-Urban

Proposed Residential

Residential Units-Agricultural

Residential Units-Rural

Residential Units-Vacation

Residential Units-Suburban

Residential Units-Urban

Commercial System

Commercial-Limited

Commercial-General

Proposed Commercial

Commercial Units

Cultural Characteristics (Continued)

Industrial System

Industrial-Light

Industrial-Extractive

Industrial-Heavy

Proposed Industrial

Industrial Units

Communication System

Communication-Interchange

Communication-Air Field

Communication-Rail Terminal

Communication-Federal Highway

Communication-State Highway

Communication-County Highway

Communication-Local Roadway

Communication-Railway

Communication-Power Transmission Line

Communication-High Pressure Oil Line

Communication-Gas Line

Communication-Telephone Cable

Communication-Proposed Principal Arterial

Communication-Proposed Primary Arterial

Communication-Proposed Standard Arterial

Communication-Proposed Minor Arterial

Communication-Proposed Collector

Institutional System

Institutional-Religious

Institutional-Medical Related

Institutional-Educational

Institutional-Governmental

Proposed Institutional

Institutional Units

Cultural Characteristics (Continued)Agricultural System

Agricultural-Crops

Agricultural-Livestock

Agricultural-Fur, Game, Poultry

Agricultural-Plantation

Agricultural

Agricultural-Platting

Recreational System

Recreation- Wayside

Recreation-County Park

Recreation-Local Park

Recreation-State Forest

Recreation-Local Forest

Recreation-Organized Public/Private Activity

Recreation-Public Hunting or Fishing Grounds

Recreation-Wildlife Preserve

Recreation-Scientific Area

Recreation-Environmental Corridors

Recreation-River/Lake Zoning

Recreation-Scenic Easement

Recreation-Scenic Highways

Proposed Recreation

Proposed Scientific Area

Recreation-Intrinsic Resources/Wildlife

Recreation-Intrinsic Resources/Vegetation

Recreation-Intrinsic Resources/Physiographic

Recreation-Intrinsic Resources/Wetland

Recreation-Intrinsic Resources/Water

Recreation-Extrinsic Resources/Topographic Associated Structures

Recreation-Extrinsic Resources/Camps, Trails, and Accomodations

Recreation-Extrinsic Resources/Water Associated Sports and Facilities

Recreation-Extrinsic Resources/Winter Sports Facilities

Recreation-Extrinsic Resources/Publicly or Privately Owned Land and  
Associated Clubs

Cultural Characteristics (Continued)

Recreation-Extrinsic Resources/Water Associated Projects  
Recreation-Extrinsic Resources/Wildlife and Conservation  
Recreation-Extrinsic Resources/Historic Structures  
Recreation-Extrinsic Resources/Historic Feature  
Recreation-Extrinsic Resources/Cultural Structures  
Recreation-Extrinsic Resources/Cultural Feature  
No Discernable Use

● Generated Data

Stream N-S Orientation  
Stream NE-SW Orientation  
Stream E-W Orientation  
Stream SE-NW Orientation  
Stream Random Orientation  
Minor River N-S Orientation  
Minor River NE-SW Orientation  
Minor River E-W Orientation  
Minor River SE-NW Orientation  
Minor River Random Orientation  
Major River N-S Orientation  
Major River NE-SW Orientation  
Major River E-W Orientation  
Major River SE-NW Orientation  
Major River Random Orientation  
Stream - Without Game Fish  
Stream - Trout  
Stream - Small Mouth Bass  
Stream - Panfish  
Stream - Walleye/Muskellunge  
Minor River - Without Game Fish  
Minor River - Trout  
Minor River - Small Mouth Bass  
Minor River - Panfish  
Minor River - Walleye/Muskellunge



Generated Data (Continued)

Lake-50 Acrea (-) Without Game Fish  
Lake-50 Acrea (-) Trout  
Lake-50 Acres (-) Small Mouth Bass  
Lake-50 Acrea (-) Panfish  
Lake-50 Acrea (-) Walleye/Muskellunge  
Lake - Without Game Fish  
Lake - Trout  
Lake - Small Mouth Bass  
Lake - Panfish  
Lake - Walleye/Muskellunge  
Soil Suitability as Subgrade  
Soil Erodibility Potential  
Soil Productivity Potential  
Highway Intersections  
Federal Highways - N-S Orientation  
Federal Highway - NE-SW Orientation  
Federal Highway - E-W Orientation  
Federal Highway - SE-NW Orientation  
Federal Highway - Random Orientation  
State Highway - N-S Orientation  
State Highway - NE-SW Orientation  
State Highway - E-W Orientation  
State Highway - SE-NW Orientation  
State Highway - Random Orientation  
County Highway - N-S Orientation  
County Highway - NE-SW Orientation  
County Highway - E-W Orientation  
County Highway - SE-NW Orientation  
County Highway - Random Orientation  
Railway - N-S Orientation  
Railway - SE-SW Orientation  
Railway - E-W Orientation  
Railway - SE-NW Orientation  
Railway - Random Orientation

Generated Data (Continued)

Power Transmission Line - N-S Orientation  
Power Transmission Line - NE-SW Orientation  
Power Transmission Line - E-W Orientation  
Power Transmission Line - SE-NW Orientation  
Power Transmission Line - Random Orientation  
High Pressure Oil Line - N-S Orientation  
High Pressure Oil Line - NE-SW Orientation  
High Pressure Oil Line - E-W Orientation  
High Pressure Oil Line - SE-NW Orientation  
High Pressure Oil Line - Random Orientation  
Gas Line - N-S Orientation  
Gas Line - NE-SW Orientation  
Gas Line - E-W Orientation  
Gas Line - SE-NW Orientation  
Gas Line - Random Orientation  
Telephone Cable - N-S Orientation  
Telephone Cable - NE-SW Orientation  
Telephone Cable - E-W Orientation  
Telephone Cable - SE-NW Orientation  
Telephone Cable - Random Orientation

● Natural Characteristics

Hydrological Systems  
Ecological Systems  
Physiographical Systems  
Pedological Systems

● Cultural Characteristics

Existing Land Use Systems  
Projected Land Use Systems  
Population Distribution Systems  
Communication Systems

Where meaningful a cell is described by the appropriate percentage of the land devoted to the various data based uses. This data base is then used by a team of specialists to develop, for each cell, a list of determinants consisting of:

- Engineering Difficulty
- Cost of Construction
- Cost of Acquisition
- Projected Traffic Generation
- Impact on the Cultural System
- Impact on the Ecological System
- Impact on Quality Agricultural Land
- Scenic Potential
- Impact on Recreation and Conservation Lands
- Development of Joint Communications Corridors

The determinants are calculated by linear models which include the data base elements which influence the individual determinants. The coefficient assigned to a particular data base element represents its significance for a particular determinant.

The program can then assign a score to a proposed alternative by appropriately weighting the determinants of the cells involved in the proposal. A highway routing problem offers a good example of the process. The program can give the construction cost, ecological impact and scenic potential scores for the two proposed routes. There exists some appropriate weighting for these factors. If these were the only three factors, for example, and if construction costs (based upon ground slope, soil type, excavation costs, etc.) were identical tradeoff between relative merits of ecological impact and scenic potential could be made. On the other hand, if some quantitative assessment of the tradeoffs among the various is provided to the program it can select an optimal route through the use of a dynamic programming algorithm.

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9. King, Leslie J., "Models of Urban Land-Use Development," Battelle Memorial Institute, Columbus, Ohio, October 1969.
10. Alonso, W., "The Quality of Data and the Choice and Design of Predictive Models," Highway Research Board Special Report, No. 97, Washington, D.C., (Referenced in Reference 9).

APPENDIX A

SOURCES OF ENVIRONMENTAL/RESOURCE INFORMATION

SECTION I.

HATS SURVEY CONTACT SUMMARY

Environmental Protection Agency  
Office of Research and Monitoring  
Research Information Division  
401 M Street SW.  
Washington, D. C. 20460

Regional Modeling Data Base  
Oak Ridge National Laboratory  
P. O. Box X  
Oak Ridge, Tennessee 37830

National Referral Center  
Science and Technology Division  
The Library of Congress  
Washington, D. C. 20540

Southeastern Wisconsin Regional Planning Commission  
Waukesha, Wisconsin

Battelle Memorial Institute  
Urban Studies Center  
Cleveland, Ohio 44106

Institute for Environmental Studies  
University of Wisconsin  
Madison, Wisconsin

U.S. Water Conservation Laboratory  
4331 E. Broadway  
Phoenix, Arizona 85040

Texas Water Development Board  
P. O. Box 13087  
Capitol Station  
Austin, Texas 78711

Institute of Urban and Regional Research  
University of Iowa  
Iowa City, Iowa

HATS SURVEY CONTACT SUMMARY (Continued)

Southern Plains Branch  
Soil and Water Conservation Research Division  
Agricultural Research Service  
U.S. Department of Agriculture  
Weslaco, Texas

Hydrologic Engineering Center  
U.S. Army Corps of Engineers  
Davis, California

Texas Water Quality Board  
Houston, Texas

Brevard County Planning Department  
Titusville, Florida

Water Resource Division  
U.S. Geological Survey  
Austin, Texas

U.S. Environmental Protection Agency  
(National Environmental Information Symposium)  
Cincinnati, Ohio

Metropolitan Washington Council of Governments  
Washington, D. C.

Division of Planning Coordination  
Executive Department, State of Texas  
Austin, Texas

Office of Assistant Director for Science  
and Technology  
National Science Foundation  
1800 G. Street,  
Washington, D. C.

Gulf Universities Research Consortium  
Galveston, Texas



## HATS SURVEY CONTACT SUMMARY (Continued)

Geographic Applications Program Office  
U.S. Geological Survey  
Washington, D.C.

Environmental Information System Office  
Oak Ridge National Laboratory  
Oak Ridge, Tennessee

Hydrologic Research and Development Laboratory  
National Weather Service  
Washington, D. C.

Environmental Sciences Group  
National Environmental Satellite Service  
National Oceanic and Atmospheric Administration  
Washington, D. C.

Alexander, R. M.  
U.S.G.S. Geographic Appl. Prog.  
Rm., 5212, GSA Bldg.  
Washington, D.C. 20242

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Army Coastal Eng'g. Res. Ctr.  
5201 Little Falls Rd., N.W.  
Washington, D.C. 20016

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University of Washington  
Seattle, Washington 98105

Blanchard, Bruce  
Southern Great Plains  
Watershed Research Center  
P. O. Box 400  
Chickasha, Oklahoma 73018

Bouchillon, C. W.  
Institute for Environmental Studies  
Drawer GH  
State College, Miss. 39762

Burgy, Robert H. Dr.  
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University of Calif.  
Davis, Calif. 95616

Callaway, Richard J.  
Pacific NW Water Laboratory  
Corvallis, Ore. 97330

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University of Alaska  
Fairbanks, Alaska 99701

HATS SURVEY CONTACT SUMMARY (Continued)

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Region 7, Federal Center  
Denver, Colorado 80225

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Earth Resources Directorate  
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Madison, Wisconsin 53706

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Mulford Hall  
University of California  
Berkeley, Calif. 94720

Cooper, Saul  
N.E. Div.  
U.S.A. Corps of Engr.  
424 Trapelo Road  
Waltham, Mass. 02154

Culler, Richard G.  
U.S.G.S.  
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Tucson, Arizona 85717

De Lozada, Antonio S.  
Bolivian Embassy  
1145 19th St. N.W.  
Washington, D.C. 20036

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HATS SURVEY CONTACT SUMMARY (Continued)

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Cornell University  
Ithaca, New York 14850

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U.S.G.S. Remote Sensing  
801 19th St., N.W.  
Washington, D.C. 20242

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P. O. Box 14  
Wageningen, The Netherlands

Downing, David P.  
Boston University  
Boston, Massachusetts 02215

Drew, James V. Dr.  
412 Administration Bldg.  
University of Nebraska  
Lincoln, Nebraska 68508

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Univ. of Calif.  
Santa Barbara, Calif. 93106

HATS SURVEY CONTACT SUMMARY (Continued)

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Bureau of Economic Geology  
University of Texas at Austin  
Austin, Texas

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University of Texas at Austin  
Austin, Texas 78712

Fryrear, D. W.  
USDA Big Spring Field Station  
P.O. Box 909  
Big Spring, Texas 79720

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Instituto Geografico Nat'l.  
Av Las Americas 5-76  
Zona 13  
Guatemala City, Guatemala

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Direccion Nacional de Economia  
Y Sociologia Rural  
Paseo Colon 974-3 Piso-Of:143  
Buenos Aires, Argentina

Goosen, D., Dr. IR.  
Inter. Inst. for Aerial  
Survey & Earth Sciences (ITC)  
P. O. Box 6  
Enschedf, The Netherlands

Grabau, Warren E.  
U.S. Army Engineer  
Waterways Exp. Station  
P. O. Box 631  
Vicksburg, Miss. 39180

HATS SURVEY CONTACT SUMMARY (Continued)

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U.S.D.A., A.R.S., E.N.T.  
Brown Soft Scale Invest.  
509 W. Fourth St.  
Weslaco, Texas 78596

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Tri State Regional Planning  
100 Church Street  
New York, N. Y. 10007

Heady, Earl O.  
Iowa St. U. of Science & Tech.  
Ames, Iowa 50016

Heller, Robert C.  
Pacific SW Forest & Range Sta.  
U.S. Dept. of Agriculture  
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HATS SURVEY CONTACT SUMMARY (Continued)

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8809 Satyr Hill Rd.  
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Australia

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P.O.Box 6732  
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136 Bis. Rue de Grenelle  
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HATS SURVEY CONTACT SUMMARY (Continued)

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Woods Hole, Mass. 02543

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Agricultural Experiment Sta.  
University of California  
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HATS SURVEY CONTACT SUMMARY (Continued)

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University of Wisconsin  
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Macleod, Norman  
Code 652  
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Goddard Space Flight Center  
Greenbelt, Maryland 20771

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U.S. Army Corps of Engineers  
5201 Little Falls Rd., N.W.  
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Iowa State University  
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HATS SURVEY CONTACT SUMMARY (Continued)

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HATS SURVEY CONTACT SUMMARY (Continued)

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U.S. Geological Survey  
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HATS SURVEY CONTACT SUMMARY (Continued)

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Raje, Surendra Anant  
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Jet Propulsion Laboratory  
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HATS SURVEY CONTACT SUMMARY (Continued)

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345 Middlefield Rd.  
Menlo Park, Calif. 94025

Rey, Paul Augustin  
Directeur du Service de la  
Carte of la Vegetation  
Cnrs D.P. 4009-31  
Toulouse, France

Ruggles, Fred H.  
U.S. Geological Survey  
Hartford, Conn. 06101

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Willow Run Laboratories  
P.O. Box 618  
Ann Arbor, Michigan 48107

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Texas Christian Univ.  
Fort Worth, Texas 76129

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Stanford Research Institute  
333 Ravenswood Ave.  
Menlo Park, Calif. 94025

Simonson, Gerald H., Dr.  
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Oregon State Univ.  
Corvallis, Ore. 97331

Simpson, Robert R.  
Dept. of Geography  
Dartmouth College  
Hanover, N.H. 03755

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Minn. State Planning Agency  
802 Capitol Square Bldg.  
St. Paul, Minn. 55161

HATS SURVEY CONTACT SUMMARY (Continued)

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Institute of Ecology  
Univ. of Wisconsin  
Madison, Wisconsin 53706

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Cambridge, Mass. 02138

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Nat'l. Marine Fisheries Service  
Miss. Test Facility  
Bay St. Louis, Miss. 39520

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Maine State Highway Dept.  
Box 1208  
Bangor, Maine 04401

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2345 Walnut St.  
St. Paul, Minn. 55113

Swanson, Lawrence  
N808  
NOAA, National Ocean Survey  
Rockville, Maryland 20852

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Geological Inst.  
State University  
Rozjer 44  
B-9000 Gmment, Belgium

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311 W. Preston Street  
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HATS SURVEY CONTACT SUMMARY (Continued)

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Berkeley, Calif. 94720

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Wildlife & Range Sciences  
University of Idaho  
Moscow, Idaho 83843

Trezek, George J.  
Univ. of Cal. Berkeley  
Berkeley, California 94720

Van Tries, Bill J.  
EROS Coordination  
Bur. of Fisheries & Wildlife  
Washington, D. C. 20240

Vega, Nestor, Dr.  
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Quito, Ecuador

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Hautes Etudes  
61 Rue Buffon  
75 Paris, France

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Box 250  
Missouri Geological Survey  
Rolla, Missouri 65401

Von Steen, Donald M.  
U.S.D.A. R&D Branch  
Statistical Reporting Service  
South Bldg. Rm. 4833  
Washington, D.C. 20250

HATS SURVEY CONTACT SUMMARY (Continued)

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East Lansing, Michigan 48823

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HATS SURVEY CONTACT SUMMARY (Continued)

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Univ. of Michigan  
Ann Arbor, Michigan 48104



## SECTION II

### INFORMATION CENTERS

#### 2.1 Environmental Information Systems Office (EISO) Oak Ridge National Laboratory (ORNL) Oak Ridge, Tennessee 37830

The primary function of EISO is to develop or correlate the information activities of the environmental research projects in progress at ORNL. EISO has developed several information data bases with data holdings comprised of on-line and off-line computer files of bibliographic and numerical data sets and hard-copy collections dealing with specific sub-sets of information not machine readable. Following is only a representative number of information centers and data bases at ORNL.

<u>Data Base</u>	<u>Telephone</u>
Regional Modeling Data Base Candi Kelly	(615) 483-8611 Ext. 3-1732 3-6560
Social Sciences Data Base Ruth E. Kemper	(615) 483-8611 Ext. 3-1732 3-6781
Eastern Deciduous Forest Biome Information Center N. Ferguson	(615) 483-8611 Ext. 3-1464
Ecological Sciences Information Center	(615) 483-8611

#### 2.2 National Referral Center Science and Technology Division Library of Congress, Washington D. C. 20540

The center is concerned with the physical, biological, social, and engineering sciences and the many technical areas related to them, in addition to all types of information resources, wherever they exist.

The following publications compiled by the center and published by the Library of Congress, under the general title, A Directory of Information Resources in the United States, may be purchased from the superintendent of documents, U.S. Government Printing Office, Washington, D.C. 20402; (1) Physical Sciences, Engineering (2) Biological Sciences (3) Social Sciences (4) General Toxicology (5) water.

2.3 National Technical Information Service (NTIS)  
U.S. Department of Commerce  
Springfield, Virginia 22151

NTIS is the central source for the public sale of government sponsored research and development reports. NTIS offers a computer generated custom bibliographic search service of the more than 300,000 abstracts of federally sponsored documents published since 1964. Copies of the full texts of most of the original reports are also available.

Weekly Government Abstract Newsletters containing abstracted documents are available under the following titles; (1) environment, pollution, and control (2) transportation (3) materials science (4) computer, control, and information theory (5) management practice and research.

2.4 Environmental Protection Agency  
National Environmental Research Center  
Analytical Quality Control Lab  
1014 Broadway, Cincinnati, Ohio 45202  
Contact - Mr. Cornelius Weber, (513) 684-2913

The agency operates an analytical methodology information center with a direct-access computerized literature file. It also publishes a monthly abstract bulletin and provides special search and information analysis services.

2.5 Air Pollution Technical Information Center  
Research Triangle Park, North Carolina 27711  
Contact - Mr. Peter Halpin, (919) 549-8411, ext. 2131

The center collects, stores, retrieves, reproduces, and disseminates needed air pollution technical information. Coverage includes journal articles, patents, government reports, preprints, technical society papers, and proceedings. It also provides literature searches and prepares a monthly abstract bulletin.

2.6 Water Resources Scientific Information Center  
Department of the Interior,  
Washington, D.C. 20204

The center publishes the biweekly selected water resources abstracts journal of literature and the annual Water Resources Research Catalog of research and development contracts. It also provides retrospective literature searches.

## SECTION III

### DIRECTORIES

#### 3.1 Directory of Environmental Information Sources

Published by the Environmental Information Systems Office, Oak Ridge, National Laboratory, Oak Ridge, Tennessee 37830, the directory lists information centers, research projects, and individual investigators. It serves to aid research administrators, scientists, group leaders, and information specialists who have an immediate need to be able to contact active workers in a particular field or to obtain environmental information. The names of 216 federally or commercially sponsored information centers are contained within the directory as depicted in the following format:

85.

Science Information Exchange  
300 Madison National Bank Bldg.  
1730 M St., NW  
Washington, D.C. 20036  
PH202-381-5511

DIRECTOR: Dr. Monroe Freeman

SPONSOR: Assistant Secretary for Science,  
Smithsonian Institution

MISSION: To facilitate effective planning and management of scientific research activities supported by U.S. agencies and institutions by promoting the exchange among participating agencies of information on all types of current basic and applied research. This includes the accumulation, organization, analysis, and maintenance of a comprehensive inventory of current research project summaries, and the making of this information available to the scientific community in a form such that maximum use can be made of this data by the scientist and research administrator.

#### 3.2 1972 Conservation Directory

The directory is published as a conservation education service of the National Wildlife Federation, 1412 16th Street, N.W., Washington, D.C. 20036. It contains a listing of organizations, agencies, and officials concerned with natural resource use and management (see appendix 1, section 4) and are cataloged within the directory in the format depicted on the following page:

TEXAS

WATER QUALITY BOARD, 314 W. 11th  
St., Austin 78701. Address mail to:  
P.O. Box 13246, Capitol Station,  
Austin 78711

(To maintain the quality of the waters of  
the State consistent with the publics  
health and enjoyment. Created: 1967)

Chairman: Gordon Fulcher

Vice Chairman: Jerry Brownlee

Executive Director: Hugh C. Yantis(512,  
475-2651)

Deputy Director: Joe P. Teller(475-3761)

Field Services Director: Dick  
Whittington (475-2768)

3.3 Directory of Information Resources in the United States - Water

The directory is published by the National Referral Center for the Science and Technology Division, Library of Congress, Washington, D.C. 20540 with the support of the National Science Foundation. It contains descriptions of more than 600 organizations and institutions able to meet specific information needs in the broad subject area of water. Included in the directory are libraries, information centers, professional societies, university research activities, and government offices. Each information resource is described according to its areas of interest, holdings, publications, and services as displayed in the format on the following page.

## TEXAS WATER DEVELOPMENT BOARD

Sam Houston State Office Building  
P.O. Box 12386, Capitol Station  
Austin, Texas 78711  
Tel: 475-3187 (Area code: 512)

Areas of Interest: Ground water and surface water hydrology; surface water hydrography, runoff, evaporation and sedimentation; water level measurement in wells and reservoirs; water use and water requirements for municipal, industrial, recreational, and agricultural uses; water use projections; flood control, navigation, and hurricane flood protection; design and cost of hydraulic structures and conveyance systems; water quality control; pumpage and diversion rates; surface casing; subsurface disposal of oil field and other wastes; economic analysis of water systems and resources; hydroelectric power generation; underground recharge of aquifers; weather modification; desalination of sea water and of saline or brackish ground water; economics of desalination; return flow of used water--quantity and quality, and its effect on downstream use of water, including bays and estuaries; topographic mapping; water resources planning to assist water rights administration.

Holdings: Technical reference library of over 20,000 books, bibliographies, technical reports, standards and specifications, 100 journals and other published material.

Publications: Three series include Reports, describing the Board's own investigations; Circulars, containing annotated bibliographies on ground and surface water; and the monthly newsletter, Texas Water Conditions. Other publications include Memorandum Reports; Limited-Distribution Reports; Water Resources Planning Reports; Rules, Regulations and Modes of Procedure of the TWDB; and the Biennial Report to the Governor and Legislature. An information press release on each Report is available on request, and single copies of most Reports and other publications are distributed free.

Information Services: Answers inquiries, prepares technical summaries, and provides referral services. Library collection may be used on site, and reference service is provided. Limited interlibrary service is offered and duplication services are available at cost.

### 3.4 Directory of State and Local Environmental Libraries

This directory was compiled by the Library Systems Branch, Environmental Protection Agency Headquarters, Washington D.C. It is an attempt to gather the names and addresses of the many libraries now involved in the collection and dissemination of environmental literature.

### 3.5 1971-1972 Pollution Control Directory

The directory is published by the American Chemical Society, 1155 16th Street, N.W., Washington, D.C. 20036. The directory lists manufacturers and suppliers of pollution control equipment, products, and services. It includes a calendar of meetings, exhibits, and conventions concerned with environmental management and a selected list of significant books on environmental matters.

### 3.6 1971 Directory of Organizations Concerned With Environmental Research

The directory is published by the Lake Erie Environmental Studies Center, State University College, Fredonia, New York 14063. It lists organizations in 68 countries, including information about the focus of research activities and the type of organizational structure.

### 3.7 1971 Directory of Environmental Information Sources

The directory is published by the National Foundation for Environmental Control, 151 Tremont Street, Boston, Massachusetts, 02111. It lists over 2300 sources of environmental information, including government agencies, educational institutions, organizations, serials and periodicals, documents and reports, conference and symposium proceedings, books, and filmstrips.

SECTION IV

1972 Conservation Directory Contents  
National Wildlife Federation  
Washington D.C.

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ENVIRONMENTAL SCIENCE LIBRARIES

<u>Address</u>	<u>Contact</u>
<u>Library</u> Environmental Protection Agency 401 M. Street, SW. Washington, D. C. 20460	Miss Sarah Thomas (202) 755-0944
<u>Library</u> National Environmental Research Center Environmental Protection Agency Cincinnati, Ohio 45268	Mr. Morton Friedman (513) 871-1820
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<u>Library</u> Environmental Protection Agency Robert S. Kerr Water Research Center P. O. Box 1198 Ada, Oklahoma 74820	Ms. Lorene Fuller (405) 332-8800
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<u>Address</u>	<u>Contact</u>
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<u>Southwest Research Institute</u> 8500 Culebran Road San Antonio, Texas 78228	Edwin F. Vaught (512) 684-5111
<u>Texas Air Pollution Control Services</u> Technical Information File Room Texas State Department of Health 820 East 53rd Street Austin, Texas 78751	Clyde L. Biggs (512) 454-3781
<u>Texas Parks and Wildlife Department</u> 715 South Bronte Street Rockport, Texas 78382	Dolores Kleypas (713) 764-2348
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<u>Texas Water Development Board Library</u> P. O. Box 12387, Capitol Station Austin, Texas 78711	Ms. Davis (512) 475-3783
<u>Texas Water Quality Board Library</u> 314 West 11th Street P. O. Box 13246, Capitol Station Austin, Texas 78711	(512) 475-2651

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<u>Environmental Protection Agency</u> <u>Office of Water Programs</u> Monitoring and Data Support Division Washington, D.C. 20460	Mr. George Wirth (703) 557-7620
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<u>City of Dallas Urban Planning Dept.</u> <u>Urban Design Division</u> 500 South Ervay, Suite 200B Dallas, Texas 75201	(214) 744-4371
<u>Coastal Ecosystems Management, Inc.</u> <u>3600 Hutten Street</u> Fort Worth, Texas 76107	(817) 731-3727 Ms. Elizabeth L. Parker



<u>Address</u>	<u>Contact</u>
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<u>Science and Industrial Library</u> Southern Methodist University Dallas, Texas 75222	(214) 792-2275

## APPENDIX B

### LAND USE MODELS

1. TITLE: Regional Environmental Systems Analysis (RESA) Land Use Simulation Model

AUTHOR: Oak Ridge National Laboratory, Regional Environmental Systems Analysis Group

SOURCE: Oak Ridge National Laboratory, RESA Group, Oak Ridge, Tennessee

OBJECTIVE/

- PURPOSE:
1. To spatially distribute new or changing increments of population and employment in the form of land-use activities.
  2. To test policy decision variables such as comprehensive plans, transportation proposals, and siting specific activities followed by a spatial testing of the effect before implementation.
  3. To provide feedback information to the socio-economic, ecological, and political sectors of the comprehensive model.

REFERENCE: 1. ORNL-4632

Oak Ridge National Laboratory - National Science Foundation Interdisciplinary Research Relevant to Problems of our Society Progress Report of Summer Study, December 1970

2. ORNL-NSF-EP-3

The Environment and Technology Assessment Progress Report-June - December 1970, February 1971

3. New tools for Regional Planning - AIA Journal, C. R. Meyers, Jr. October 1971

4. ORNL-NSF-EP-25

Computer Display in Spatial Modeling, A. H. Voelker, C. R. Meyers, Jr. August 1972

5. ORNL-NSF-EP-7

Regional Modeling Abstracts, Vol. 1, C. R. Meyers, Jr.

6. ORNL-NSF-EP-10

Regional Modeling Abstracts, Vol. 2, C. R. Meyers, Jr. December 1971

# LAND USE MODELS (Continued)

7. ORNL-NSF-EP-23

Regional Modeling Abstracts, Vol. 3, C. R. Meyers, Jr.  
June 1972

8. Model Data Acquisition & Display, RESA Memo Report  
#72-3 by A. H. Voelker, C. R. Meyers, Jr., D. L.  
Wilson, & T. C. Tucker, October 1972

STATUS: September 15, 1972

1. Comprehensive data base including: Spatial cultural, and landscape characteristics with corresponding tabular information related to the spatial unit assignments.
2. Initial operational computer information system (Phase I, Oak Ridge Regional Modeling Information System, ORRMIS).
3. Operational programs for initial 30-second allocation indices.
4. Operational subregional selection process.

INPUT:

1. Socio-economic projections: (by total 6500 square mile region)
  - . Regional employment projections.
  - . Regional account of the number of businesses in each employment category.
  - . Regional population projections (by age and family categories).
2. Environmental (by 30-second call approximately 170 acres).
  - . Status of air and water pollution levels.
3. Land Use (by 30-second: 15-second, approximately 40 acres; and 3.75 seconds, approximately 2 1/2 acres) cells.
  - . Existing (starting) spatial land-use configuration.
  - . Initial allocation indices scores.
  - . ORRMIS spatial data base

REGIONAL

LOCATION: Knoxville, Tennessee and its surrounding sphere of regional influence (corresponding political boundaries--East Tennessee Development District (ETDD); East Tennessee).

2. TITLE: National Environmental Models of Agricultural Policy, Land Use and Water Quality

AUTHOR: Center for Agricultural and Rural Development, Iowa State University

LAND USE MODELS (Continued)

SOURCE: Center for Agricultural and Rural Development,  
Iowa State University, Iowa 50010

OBJECTIVE: Determining the economic, interregional and social impact of policies to improve water quality through alternatives in land use--water use and agricultural policies.

STATUS: Funded by National Science Foundation in May for two years. Initial work at data assembly and model construction has been initiated.

OUTPUT: Shows what production should be in each one of 200 agricultural producing regions, 100 water supply regions and 50 market areas; shows how resources in each of the previous entities should be used for optimum pattern of agricultural production and attainment of parameterized water quality goals; expresses interregional competition and comparative advantage among previous production, water supply and market regions; indicates commodities, resources and water which should be exported from one region to another in optimal pattern of agricultural production and resource use in the United States; indicates extent to which land should be substituted for water and vice versa in attaining economic optimum of agriculture structure and environmental quality goals; analyzes the effect of various agricultural policies and land and water investment programs in affecting resource efficiency and allocative needs for various water quality goals; generates income by producing region and farm class of different policies to control environment through land use, water use and technology of agriculture; investigates extent to which changes in water and land use can be substituted in meeting national food needs as technology relating to fertilizers, insecticides and so forth, are restricted in control of water resources input. An extremely large amount of data on water supplies yields under various technologies, land classes by slope, group and length, livestock production coefficients and yields, labor requirements, cap requirements, and so forth for every crop produced under all alternative technologies in each of 200 producing regions of the United States.

3. TITLE: Empiric Activity Allocation Model
- AUTHOR: Peat, Marwick, Mitchell & Company  
1025 Connecticut Ave., N. W.  
Washington, D.C.

LAND USE MODELS (Continued)

SOURCE: Department of Regional Planning  
Metropolitan Washington Council of Governments  
Washington, D.C.

ABSTRACT: The "Empiric" Model is designed to allocate projected regional population, employment, and land-use growth between a set of smaller sub-regions or districts. The model is designed to perform three specific functions: (1) To generate small-area forecasts of population, employment and land-use, based on exogenously specified regional totals and exogenously specified planning policies. (2) To evaluate the impact of alternative public and private planning policy decisions on the future distribution of regional activity. (3) To serve as mechanism for analyzing, interrelating, and coordinating future public policy decisions.

4. TITLE: A Regional Economic Simulation Model

AUTHOR: Southeastern Wisconsin Regional Planning Commission

SOURCE: Technical Report No. 5  
Southeastern Wisconsin Regional Planning Commission  
Waukesha, Wisconsin

ABSTRACT: The Regional Economic Simulation Model was developed and applied as part of the Regional Land Use-Transportation Study of the Southeastern Wisconsin Regional Planning Commission. The function of the model is to provide a series of regional employment and population forecasts required as inputs to the land use-transportation planning sequence. The model also allows for the dynamic analysis of inter-industry relationships for the regional economy. Difference equations are used to simulate inter-industry relationships over time. This introduction of the dynamic dimension of time differentiates this model from most input-output models developed in the past, which have been static in nature.

Primary data obtained from small samples of firms in various industries were used in preparing parameter estimates for the model. These primary data were supplemented by state corporate tax and employment records and other secondary sources, such as the U. S. Department of Commerce input-output tables.

Historical simulation tests were conducted over the 1946-1960 period. Comparisons of model outputs with historical data indicated an error of 2.99 percent in the overall employment level forecast by the model for 1960 from 1946

## LAND USE MODELS (Continued)

initial conditions, when that level was compared with actual 1960 employment levels. Errors in major industry component forecasts ranged from 0.8 percent in manufacturing to 19.6 percent in private services and education. Future employment levels were forecast for the 1970-1990 period using the simulation model. These forecasts were somewhat higher than those developed using non-model techniques developed and applied by the Commission.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

5. TITLE: The Present and Futures of Urban Land-Use Models  
 AUTHOR: D. R. Seidman  
 SOURCE: Proceedings, Fourth Annual Conference on Urban Planning Information Systems and Programs, PG 119-128 (1966)  
 ABSTRACT: Begins with review of Delaware Valley RPC activities allocation model which involves 7 sub-models for 192 districts in Philadelphia. Models are solved in sequence for series of 5-year recursive steps, 1960-1985. Discusses calibration results and forecasting runs. Reviews other land-use models especially with respect to problems of areal aggregation and calibration, and long range versus short range forecasting.

\* \* \* \* \*

6. TITLE: A Land Use Plan Design Model, Vol. 1 - Model Development  
 AUTHOR: Southeastern Wisconsin Regional Planning Commission  
 SOURCE: Southeastern Wisconsin Regional Planning Commission, Waukesha, Wisconsin  
 ABSTRACT: A model was designed that could be used to synthesize land use plans that would satisfy predetermined design criteria and minimize the use of financial resources. The urban design problem is defined and the basic approach to its solution using a land use plan design model with supporting input data and computer programs is generally described. The state of the art of design models is discussed and the design system is presented in detail including the definition of design modules, objectives, design standards, and development cost functions. The theory and operation of the model is described as exemplified in a pilot test in a small Wisconsin community.

LAND USE MODELS (Continued)

7. TITLE: A Land Use Plan Design Model, Vol. 2, Model Test  
 AUTHOR: Southeastern Wisconsin Regional Planning Commission  
 SOURCE: Southeastern Wisconsin Regional Planning Commission, Waukesha, Wisconsin  
 ABSTRACT: The existing model was refined with particular attention to more specifically defining the input data requirements, developing a computer program for the efficient reduction of input data, and improving the mathematical structure of the model itself. The refined model was tested for internal consistency and workability and applied to develop a land use plan for an actual urban region. The model generated land use plan is compared with a land use plan developed for the same urban region by more conventional graphic and analytical land use planning techniques.

8. TITLE: A Land Use Plan Design Model  
 AUTHOR: K. J. Schlager  
 SOURCE: Journal of the American Institute of Planners, 31(2)  
 ABSTRACT: The process of comprehensive planning may be susceptible to a computer solution. The nature of the problem is described and an experimental solution is defined through the use of linear programming. In this solution, the objective is to minimize total public and private investment costs subject to a number of design restraints which the planner is free to manipulate. The output of the program is a complete land use plan. Other and more sophisticated methods of solution are discussed briefly.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

9. TITLE: Seven Models of Urban Development - A Structural Comparison  
 AUTHOR: I. S. Lowry  
 SOURCE: Rand Corp., Santa Monica, California  
 ABSTRACT: The Significance of the variables included in model building and the coherence of the models formal structure are emphasized. An adequate system of interdependence is spelled out by the theory of the market for urban land, the formal structure of which is elaborate but easily grasped. In choosing a model for a particular purpose consideration must be taken of both omissions and inclusions. A theory of the

## LAND USE MODELS (Continued)

urban land market is presented in paradigm which provides a number of important variables and relationships among variables. Seven specific models are reviewed in detail. Each was chosen to illustrate a particular strategy of simplification. The formal structure of the models, the conceptual definitions of specific variables in particular, is carefully considered.

The models discussed, and their major focus, are as follows:

- (1) Land use: The Chicago Area Transportation Study
- (2) Land use succession: The University of North Carolina Model
- (3) Location: Empiric Model
- (4) Migration: Polimetric Model
- (5) Hydrid: Pittsburgh Model
- (6) Market Demand: Penn-Jersey Model
- (7) Market Supply: San Francisco Model.

\* \* \* \* \*

\* \* \* \* \* NON-MODEL \* \* \* \* \*

10. **TITLE:** Models and Techniques for Urban Planning

**AUTHOR:** Douglas B. Lee

**SOURCE:** National Technical Information Service  
Report No. AD 843-620  
Springfield, Virginia 22151

**ABSTRACT:** The intent of the report was to provide an information base for primarily technically skilled people who might be interested in applying quantitative methodology to the modeling of urban phenomena. Thus we have tried to indicate how techniques might be applied, and also how they have been applied in the past to urban problems. Land use models were selected as the main area of interest, but the topic is extremely open-ended, and difficult to define, with the result that the report lacks a certain kind of elegance.

Chapters 1-5 proceed from the general to the specific. Chapter 2 describes a number of abstract attributes of models which provide a framework for further discussion. Chapter 3 sketches out a variety of concepts and techniques that seem to be relevant to urban models, and attempts to relate these concepts to modeling of social activities. Chapter 4 is an overview of the modeling process, emphasizing those aspects that are critical to urban modeling. These three chapters abstract as much as possible of what can be said about urban modeling, with the 5th chapter being a description of the specifics of several applications. Finally, Chapter 6 gives a summary and suggested further work.



LAND USE MODELS (Continued)

11. TITLE: Interstate 57 - An Application of Computer Technology to Highway Location Dynamics
- AUTHOR: B. J. Niemann, Jr.; A. H. Miller
- SOURCE: Environmental Awareness Center, Department of Landscape Architecture, School of Natural Resources, University of Wisconsin, Madison, Wisconsin
- ABSTRACT: The development of the Interstate corridor selection process consists of 4 phases: data bank development; corridor determinant establishment; corridor alternative analysis; and corridor selection. The conceptual focus of the process procedure was the creation of a system which provides for interaction among interested and affected parties by first establishing an objective data system. The process provides a forum and a method through which interaction can occur. The method also provides analyses by which various corridor effects can be understood. Finally, the process assists in the actual location of a corridor.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

12. TITLE: Review of Existing Land-Use Forecasting Techniques
- AUTHOR: N. A. Irwin
- SOURCE: Highway Research Record, 88, 182-216
- ABSTRACT: The Boston Regional Planning Project (BRPP) has retained the Traffic Research Corporation (TRC) to develop and apply for preliminary forecasts a mathematical model for estimating future distributions of population, land use and economic activities in the Boston region. BRPP plans to use this model as a device for testing and evaluating the probable future effects of transportation facilities, zoning policies, and possibly other factors under planning control on the distribution and density of development patterns throughout the region. Most urban transportation planning studies during the past decade have produced or are producing estimates of future land use in all subregions of the areas which have been or are under study, mainly to provide a basis for estimating future traffic demand. (In this context, land use includes population and economic activities as well as structures and land areas.) Methods employed for these land-use estimates have ranged from largely intuitive or judgmental projections to systematic techniques based on a chain of quantitative reasoning which could be reproduced by another group. The present review insures that existing techniques are fully utilized, where pertinent, in the development of a land-use forecasting model for the Boston region.

\* \* \* \* \*

LAND USE MODELS (Continued)

13. TITLE: Prototype Development of a Statistical Land Use Prediction Model for the Greater Boston Region
- AUTHOR: D. M. Hill; D. Brand; W. Hansen
- SOURCE: Highway Research Record 114, 51-70
- ABSTRACT: Traffic Research Corporation has developed and tested a prototype model for the subregional distribution of population and employment growth in a metropolitan area. The model, called the EMPIRIC model, requires externally specified regional growth totals for population and employment categories to be projected. Validity checks were carried out by applying the model to forecast 5 categories of population and employment from 1950 to 1960 for 29 subregions and comparing the observed and calculated subregional activity levels for 1960. Root-mean-square error ratios obtained with prototype EMPIRIC Model Application 3 were about 1 and 3% for total population and total employment, respectively. The results seem to confirm the hypothesis that urban land use may be predicted on a subregional level, using an "associative" or "statistical" model of the EMPIRIC type, with sufficient accuracy for land-use and transportation planning purposes. The use of such a model enable planners to study systematically the effects of transportation facilities, land-use controls and other policies on urban development and to produce staged plans and policies which take these interactions into account.
14. TITLE: Empiric Land Use Forecasting Model, Final Report, Development and Calibration of the Model for 626 Traffic Zones
- AUTHOR: Traffic Research Corporation
- SOURCE: Metropolitan Area Planning Council, Depart. of Commerce and Development, Washington, D.C.
- ABSTRACT: The EMPIRIC Land Use Forecasting Model is a technique, programmed for an electronic computer, which distributes future year regional totals of urban activities such as population and employment. The model was designed to produce land use forecasts which could be used as input to traffic forecasting techniques being applied for the region, and to be sufficiently sensitive to public policy inputs so that the model could be used as a regional planning tool to test alternative development plans.

# LAND USE MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

15. TITLE: Land Use Analysis in Metropolitan Transportation Studies - A Summary of Methods  
AUTHOR: M. Trevithick  
SOURCE: Institute of Transportation and Traffic Engineering, Berkeley, California  
ABSTRACT: Various methods of forecasting land-use in metropolitan areas that have been employed in major transportation studies are identified. The logic of the structure underlying existing methods is reviewed and several theoretical models were briefly described. All of the transportation studies reviewed use land analysis as a prime ingredient of the planning process attitudes towards the purpose of the land use. Analysis varied extensively among the studies.

\* \* \* \* \*

16. TITLE: Land Use Simulation Models; New Horizons in Comprehensive Planning for Urban Growth and Change  
AUTHOR: P. F. Wendt  
SOURCE: Town Planning Review, 41(2), 161-167  
ABSTRACT: Land use simulation models promise new opportunities for analysis of the impact of changes in employment, transportation and housing upon future land uses. These models vary in their structure, operating characteristics and range of application. The Bay Area Simulation Model is discussed in some detail. It is a large complex of computer models which has as its goal forecasting future growth within the San Francisco Bay Area. It is composed of 3 distinct submodels. This model provides a technique which can be applied to any area for which data are available. The basic population and employment projections upon which the model output rests require constant review and updating as national, regional, and international economic developments proceed. As knowledge of travel behavior expands, the assumptions concerning the journey from work to home and journey to shop must be updated. Basic data concerning the inventories of land in present uses and the land available for future development must be improved.

# LAND USE MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

17. TITLE: Models of Urban Land-Use Development

AUTHOR: Leslie J. King

SOURCE: Battelle, Columbus Laboratories  
505 King Ave., Columbus, Ohio 43201

ABSTRACT: The report is intended to provide a background on land-use modeling techniques and recommendations for small metropolitan areas contemplating use of these models. Emphasis is placed on those land-use studies and models that are essentially positive in their approach, that is, those that deal mainly with explanations of what has happened in urban land-use patterns and with the prediction of future developments consistent with these explanations or understandings. An annotated bibliography on land-use modeling techniques is appended to this report.

\* \* \* \* \*

18. TITLE: Report on the Activities Allocation Model

AUTHOR: D. R. Seidman

SOURCE: Penn Jersey Transportation Study, P. J. Paper No. 22,  
Philadelphia, Pennsylvania

ABSTRACT: The activities allocation model consists of 7 major submodels each of which determines either the location of a given type of activity or the amount of land that this activity uses. The model is very flexible in testing the effects of a wide range of alternative policies and can indicate those policies that deserve support and will benefit the region.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

19. TITLE: Preliminary draft: IIPS Land-Use Models, Present and Future

AUTHOR: M. A. Goldberg

SOURCE: University of British Columbia, Vancouver, British Columbia

ABSTRACT: The models described are primarily urban and include economic and residential activities. Some 27 different economic activities are to be allocated by the models. A crude algorithm for creating recreational land is included. Land use activities are lumped into 5 groups each described by a set of algorithms: manufacturing, retail trade, service, housing, recreation.

\* \* \* \* \*

LAND USE MODELS (Continued)

20. TITLE: A Retail Market Potential Model  
AUTHOR: T. R. Lakshmanan; W. G. Hansen  
SOURCE: Journal of the American Institute of Planners, 31,134-143  
ABSTRACT: Possible equilibrium distributions for large retail trade centers in the Baltimore metropolitan area are explored. Possible sites for centers are selected on general planning grounds and tested for feasibility and "balance." Balance is determined in terms of the volume of business attracted by each center in relation to its size. A balanced distribution exists in which the size of centers is related to their drawing power, which in turn depends on the distribution of purchasing power projected for the area and the transportation facilities and for trip-makers. This land use model is intimately related to transportation models, by way of network tracing and a gravity model trip distribution theory. It represents a departure from some of the restrictions of central place theory. The balanced distribution of retail outlets turns out to be the minimum cost pattern for trip-makers.
21. TITLE: A model for the Distribution of Residential Activity in Urban Areas  
AUTHOR: J. D. Herbert; B. H. Stevens  
SOURCE: Journal of Regional Science, 2(2)  
ABSTRACT: The model presented here is designed to distribute households to residential land in an optimal configuration. The model was constructed for the Penn-Jersey Transportation Study as part of a larger model designed to locate all types of land-using activity. Since the model had to be suitable for practical application a certain amount of conceptual elegance has been sacrificed in favor of operational simplicity. The larger model operates in the following way: The total relevant time period is subdivided into a number of short iterative periods. For each iterative period different types of land-using activity are handled separately. A particular type of activity is distributed in a configuration that is optimal only with respect to all previously located activities are ignored. It is assumed that they can be ignored if iterative periods are kept short enough to ensure that the number of users located in a single run of the model is small. Operating in this way we are able to achieve computational simplicity and, at the same time, recognize most of the basic interactions among land users. For the residential model, in a particular

# LAND USE MODELS (Continued)

iterative period, the number of households to be located and the amount of land that is expected to be available for residential use is forecast exogenously. A linear program is used to produce, for the end of that period, an optimal configuration of the new households on the available land. This configuration is optimal with respect to the configuration of all previously located activities, and constitutes a prediction of the way in which the forecast household will locate.

22. TITLE: Land-Use Changes in East Tennessee and a Simulation Model Which Describes These Changes for Three Counties.  
AUTHOR: J. M. Hett  
SOURCE: International Biological Program, ORNL-IBP-71-8, Oak Ridge National Laboratory, Oak Ridge, Tennessee  
ABSTRACT: Rates of change and amounts of nine land-use categories were determined for five counties in Tennessee. Using data averaged for three counties, a simulation model was devised to investigate both land-use changes and the influence of man. The influence of TVA dams and the construction of a pulp mill are obvious in the modeled predictions.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

23. TITLE: Planning Models -- Pure But Not Simple  
AUTHOR: B. Harris  
SOURCE: Institute for Environmental Studies, University of Pennsylvania, Philadelphia, Pennsylvania  
ABSTRACT: Models of consumer behavior as used for projecting transportation demand, and models of land use development as used for the projection of future urban form and of the gross location of demand for urban facilities do not meet adequate standards of planning models. A planning model must produce a plan by strongly guiding the planner in making one or more decisions which are necessary for the articulation of a plan. Caution should be used when applying models to planning.

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LAND USE MODELS (Continued)

24. TITLE: Storm Water Management Model, Vol. 1 - Final Report  
AUTHOR: Metcalf & Eddy, Inc., Palo Alto, California  
SOURCE: Contract # 11024 DOC 07/71, EPA Water Quality Office, USGPO, Water pollution Control Research Series, July 1971 (352) research report.  
ABSTRACT: A new comprehensive mathematical model, representing urban storm water runoff, assists administrators and engineers in planning, evaluating, and managing overflow abatement alternatives for combined or separate sewers. In demonstration runs on selected catchments, the amount of pollutants released varied significantly with real time occurrence, runoff intensity duration, pre-storm history, land use, and maintenance. Storage-treatment combinations offered best cost-effectiveness ratios. (numerous charts, graphs, and diagrams)
25. TITLE: Storm Water Management Model, Vol. 2 - Verification and Testing  
AUTHOR: Metcalf & Eddy, Inc., Palo Alto, California  
SOURCE: Contract # 1102 DOC 07/71, EPA Water Quality Office, USGPO, Water Pollution Control Research Series, July 1971 (172) research report.  
ABSTRACT: Verification and testing of the mathematical model designed for storm water management (explained in Vol. 1) are described. San Francisco, Cincinnati, Philadelphia, and Washington, D.C., were selected for: availability of data on rainfall and concurrent runoff hydrographs and pollutographs; wide geographical separation and contrasts in storm patterns; differences in land use, topography, population density, and income; comparison of solutions for problem areas; and city cooperation. (numerous charts, graphs, maps, and photos)
26. TITLE: Storm Water Management Model, Vol. 4 - Program Listing  
AUTHOR: Metcalf & Eddy, Inc., Palo Alto, California  
SOURCE: Contract # 1102 DOC 07/71, EPA Water Quality Office, USGPO, Water Pollution Control Research Series, July 1971 (247) statistics.  
ABSTRACT: A computer printout is presented for the storm water management model described in Vol. 1.

LAND USE MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

27. TITLE: Linear Programming and the Projection of Land Uses  
 AUTHOR: B. Harris  
 SOURCE: Penn Jersey Transportation Study, Philadelphia, Penn.  
 ABSTRACT: A commentary on the implications of the Herbert-Stevens model for the distribution of Residential Activities in Urban Areas is presented. Some aspects of that model are elaborated and modifications of others which have been determined by the Penn Jersey staff to be necessary or desirable are indicated.

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28. TITLE: Modeling the Effect of Land Use Modifications on Runoff  
 AUTHOR: C. A. Onstad; D. G. Jamieson  
 SOURCE: Water Resources Research, 6(5), 1287-  
 ABSTRACT: The natural apportionment of rainfall excess to surface and subsurface flow can mean the difference between large flow rates for a short time or more manageable flow rates over a longer time. By using available soil storage, peak flood flows can be reduced without necessarily reducing the total volume of runoff. An attempt has been made to simulate this phenomenon. The land phase of the hydrologic system has been simulated by a series of interconnected, nonlinear reservoirs and the channel phase by a single linear reservoir. By manipulation of parameters, which mathematically represent physical measurements, the watershed response to the addition of conservation practices, such as terracing, may be predicted.

29. TITLE: Building a Nonlinear Sediment Yield Model  
 AUTHOR: R. P. Betson  
 SOURCE: Proceedings of the Federal Inter-Agency Sedimentation Conference, U.S. Government Printing Office, Washington, D.C.  
 ABSTRACT: Several examples are presented, illustrating the development and solution of a complex empirical sediment yield model utilizing nonlinear least squares techniques adapted for computer analysis.



LAND USE MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

30. TITLE: Effects of Upstream Land Practices on Runoff  
 AUTHOR: G. W. Reid; H. S. Oey; P. Choate  
 SOURCE: Proceedings of the Second Annual American Water Resources Conference, University of Chicago, Chicago, Ill., Nov. 1966  
 ABSTRACT: Efforts made towards rationalizing the estimation of the effects of land use and treatment on watershed yield are reported. A rational procedure was developed which consists of applying logic, and known effects, to the problem. A method is presented for estimating water yield by use of component analysis and multiple regression techniques where precipitation, land treatment and land use are the variables.

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31. TITLE: Economic Model of Floodplain Land Use and Land Use Policy  
 AUTHOR: John P. Brown, et al, Brown University  
 SOURCE: Water Resources Research, February 1972, v8, n1, p18 (15) research report  
 ABSTRACT: Mathematical model for determining flood plain use considers flood damage, location hazards, and control policies such as flood plain zoning and relief measures. (5 graphs)

32. TITLE: A Computer Simulation Model for Flood Plain Development; Part 1: Land Use Planning and Benefit Evaluation  
 AUTHOR: N. V. Arvanitidis, et al  
 SOURCE: INTASA, Menlo Park, California, contract # DACW 07-71-C-0026, USACE, Inst of Water Resources Report 72-1, February 1972 (85) research report  
 ABSTRACT: Computer simulation model for flood plain development required a forecast of population and economic activities, allocation of activities to available land, integration of public policies restricting land use, measurement and protection of flood damages, and evaluation benefits based on appropriate formulas using flood damages reduce, land rents, and economic rent differences (locational advantages). (20 diagrams)

LAND USE MODELS (Continued)

33. TITLE: Watershed Management: A Systems Approach  
 AUTHOR: L. M. Eisel, Harvard University  
 SOURCE: Water Resources Research, April 1972, v8, n2, p326 (12 1/2) research report  
 ABSTRACT: A systems approach to land use management decision-making in wildland areas is developed and demonstrated with a hypothetical example. Model results suggest that future outdoor recreational demands and benefits are important factors in management policies. The solution of the chance-constrained model indicates that forest management practices to increase streamflows may have only a minimal effect on the design and operation of downstream reservoirs. (3 charts, 5 graphs, 1 diagram)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

34. TITLE: Regional Modeling Abstracts - Vol. I, Vol. II, Vol. III  
 AUTHOR: Charles R. Meyers, Jr.  
 SOURCE: Regional Modeling Group, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, Attn: Candi Kelly  
 ABSTRACT: 2600 abstracts of literature acquired and indexed by the Regional Modeling Team of the Oak Ridge National Laboratory-National Science Foundation Environmental Program are given. The abstracts cover literature on the development and use of mathematical models capable of simulating the economic, societal, ecological, and land use responses of a geographical region to alternative policy decisions. Access to the abstracts is achieved through various indexes: key word, author, permuted title word, and permuted key word (or phrase).

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35. TITLE: Ecological Dynamics of Watersheds  
 AUTHOR: Sigurd Olsen and Douglas G. Chapman, University of Washington  
 SOURCE: BioScience, March 1972, v22, n3, p158 (4) technical report  
 ABSTRACT: A graphic transfer function model demonstrates the pathways of energy, water, and elements within a watershed. A watershed is taken as the best example of a complete

# LAND USE MODELS (Continued)

ecosystem, containing both terrestrial and aquatic parts with their population of producers, consumers, and decomposers. This transfer model represents only the first step toward the development of quantitative, mathematical models that can serve to describe the complicated interactions between the environment and biota. (1 chart, 1 diagram)

36. TITLE: A Computer Management Game of Land Use in British Columbia  
AUTHOR: Carl J. Walters and Fred Bunnell, University of British Columbia  
SOURCE: Journal of Wildlife Management, October 1971, v35, n4, p644 (14) research report.  
ABSTRACT: Computer simulation models can be used as management games to bring together decision makers on resources. A general computer model, FARMS, is based on land use and big game populations in British Columbia. Represented in the model are plant production and succession, wildlife habitat and food selection, and dynamics of wildlife herds. A simple intervention scheme allows the user to vary harvest rates of game and trees, stocking rates of cattle, and range-burning practices. The model has proven useful in teaching students about the effects of management on wildlife populations, and may aid researchers in defining critical interactions and data requirements. (6 charts, 5 diagrams)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

37. TITLE: The Nature and Uses of Models in City Planning  
AUTHOR: A. M. Voorhees  
SOURCE: American Institute of Planners Journal, 25 (2), 50-60  
ABSTRACT: The case for developing models, especially for land use and traffic forecasting as part of the urban planning program is put forth. The advantages of using models and the general way in which models are developed, are discussed.

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38. TITLE: The Use of Land Development Simulation Models in Transportation Planning  
AUTHOR: P. F. Wendt; M. A. Goldberg

LAND USE MODELS (Continued)

SOURCE: Center for Real Estate and Urban Economics, Institute of Urban and Regional Development, University of California, Berkeley, California

ABSTRACT: The basics of the BASS model and how it can be applied to transportation planning are discussed. In a sketch of the submodels which comprise the model, the flexibility that was incorporated into the model's structure is emphasized. This flexibility allows the model to supply the needed feedback from the transportation plan to spatial arrangement of employment and residences in the region. The model could be extended to generate trip distribution internally, thus bypassing the use of separate trip distribution algorithms.

39. TITLE: A Computer-Aided Space Allocation Technique

AUTHOR: W. S. Ward; D. P. Grant

SOURCE: Part of Kennedy, M. (Ed.), Proceedings of the Kentucky Workshop on Computer Applications to Environmental Design, University of Kentucky, Lexington

ABSTRACT: The technique described here is an adaptation of the map overlay space allocation technique developed by Alexander and Manheim and by McHarg. It varies from these earlier techniques in that it substitutes a matrix of descriptor numbers for each map and in that it allows widely varying relative weights of importance to be assigned to the various parameters mapped. The intent of this technique is to provide the designer with a study model for land use and space allocation problems that allows him to combine his judgments with a data base to see what patterns of space use are implied, and that then allows him to reiterate time and time again with altered value judgments and/or modified data.

40. TITLE: A Model of Residential Land Use

AUTHOR: E. F. Brigham

SOURCE: Report No. RM-4043-RC, August 1964, The Rand Corp., Santa Monica, California

41. TITLE: Storm Water Management Model, Vol. 3 - Users Manual

AUTHOR: Metcalf and Eddy, Inc., Palo Alto, California

SOURCE: Water Pollution Control Research Series 11024 DOC 09/71, EPA Water Quality Office, September 1971

LAND USE MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

42. TITLE: Research of Existing Land-Use Models  
AUTHOR: D.D. Lamb  
SOURCE: SPRPC Report No. 00010045, March 1967, Southwestern Penn-  
sylvania Resional Planning Commission

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\* \* \* \* \* NON-MODEL \* \* \* \* \*

43. TITLE: The Appreciation of Models to the Planning Process With  
Special Emphasis on Land Use  
AUTHOR: J. B. Kracht  
SOURCE: Council of Planning Librarians Monticello, Illinois  
ABSTRACT: The sources presented relate primarily to land use models  
and transportation models which have implications for land  
use. Citations are given for basic sources, articles, mono-  
graphs, papers and reports, and dissertations.

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44. TITLE: Jobs, People, and Land  
AUTHOR: Center for Real Estate and Urban Economics  
SOURCE: Institute of Urban and Regional Development, University  
of California, Berkeley, California  
ABSTRACT: A model was developed which could be employed in analyzing  
the probable impact of change in employment, transportation  
patterns, and planned programs of urban renewal upon future  
patterns of urban growth and land use in the San Francisco  
Bay area. The geographical coverage of the model was extended  
to include 13 Bay-Delta counties. Forecasts were made of em-  
ployment, population, housing, and land use for 5-year periods  
from 1965 to 1990 and for 10-year periods continuing to 2020.  
Although the basic unit of output in the model is the census  
tract, the forecasts are summarized by counties.

## APPENDIX C

### AGRICULTURE/FORESTRY MODELS

1. **TITLE:** National Environmental Models of Agricultural Policy, Land Use and Water Quality
- AUTHOR:** Center for Agricultural and Rural Development, Iowa State University
- SOURCE:** Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa 50010
- OBJECTIVE:** Determining the economic, interregional and social impact of policies to improve water quality through alternatives in land use--water use and agricultural policies.
- STATUS:** Funded by National Science Foundation in May for two years. Initial work at data assembly and model construction has been initiated.
- OUTPUT:** Shows what production should be in each one of 200 agricultural producing regions, 100 water supply regions and 50 market areas; shows how resources in each of the previous entities should be used for optimum pattern of agricultural production and attainment of parameterized water quality goals; expresses interregional competition and comparative advantage among previous production, water supply and market regions; indicates commodities, resources and water which should be exported from one region to another in optimal pattern of agricultural production and resource use in the United States; indicates extent to which land should be substituted for water and vice versa in attaining economic optimum of agriculture structure and environmental quality goals; analyzes the effect of various agricultural policies and land and water investment programs in affecting resource efficiency and allocative needs for various water quality goals; generates income by producing region and farm class of different policies to control environment through land use, water use and technology of agriculture; investigates extent to which changes in water and land use can be substituted in meeting national food needs as technology relating to fertilizers, insecticides and so forth, are restricted in control of water resources input. An extremely large amount of data on water supplied yields under various technologies, land classes by slope, group and length, livestock production coefficients and yields, labor requirements, cap requirements, and so forth for every crop produced under all alternative technologies in each of 200 producing regions of the United States.

AGRICULTURE/FORESTRY MODELS (Continued)

2. TITLE: Development of a Cybernetic Model of an Animal - Environment System
- AUTHOR: K. K. Beer, Moscow, Russia
- SOURCE: Joint Publications Research Service Report No. JPRS 55887, 4 May 1972. National Technical Information Service, Springfield, Virginia 22151
- ABSTRACT: An "animal-environment" model, based upon the compliance of the organism to conditions of the environment according to the principle of bioecosis is described. The concept of reloconstants in a biological model is used as well as equations of regression, which characterize the effect of different factors on cow milking and which are of interest not only for the study of phenomena but also for plotting the entire mathematical apparatus of the model.
3. TITLE: A Theoretical Framework for the Photosynthetic Modeling of Plant Communities
- AUTHOR: S. B. Idso
- SOURCE: U. S. Water Conservation Laboratory  
4331 E. Broadway, Phoenix, Arizona 85040
- SUMMARY: Several simulation models of photosynthesis, transpiration, light intensity, relative humidity, and air temperature in a plant canopy are reviewed and compared. A synthesis is made of the best aspects of each, resulting in a comprehensive model of crop photosynthesis, which as a byproduct also calculates canopy profiles of all of these other parameters from values obtained over the canopy. A new photosynthesis function is developed to use in conjunction with the model which expresses net photosynthesis in single leaves as a function of incident light intensity, leaf temperature, soil moisture tension, relative humidity, and carbon dioxide concentration of the surrounding ambient air. The adaptability of the method to computer solution is stressed throughout, and details are given for its accomplishment.
4. TITLE: Estimation of Density From a Sample of Joing Point and Nearest-Neighbor Distances
- AUTHOR: C. L. Batcheler
- SOURCE: Ecology Vol. 52, Summer 71, Pg. 703-709
- ABSTRACT: Distances are measured from sample points to the nearest member of a population, from that member to its nearest neighbor, and from that neighbor to its nearest neighbor. The point-to-nearest member is used to obtain an estimate of density, which is characteristically unbiased if the population is random, but biased if the population is uniformly or contagiously distributed. The bias is

## AGRICULTURE/FORESTRY MODELS (Continued)

corrected by an exponential function of the sum of the point distances divided by the sum of either the nearest-or second-nearest-neighbor distances. The distances also provide an index of departure from randomness.

5. TITLE: Simulating Both Aerial Microclimate and Soil Temperature from Observations Above the Foliar Canopy.
- AUTHOR: Jan Goudriaan and Paul E. Waggoner.
- SOURCE: Department of Theoretical Production Ecology, Agricultural University, Wageningen, the Netherlands of Netherlands Journal of Agricultural Science 20 (1972) pg 104-124
- ABSTRACT: A simulation model is described for the daily course of microclimatic characteristics of foliar canopy and the soil underneath. The independent driving forces are the meteorological observations above the canopy. The canopy is described by its geometrical, optical and physiological properties, the soil by its thermal hydraulic properties. Comparison with real data shows a good agreement for crop transpiration, soil evaporation and soil heat flux, and to a lesser degree for air temperature and humidity and leaf temperature.
- The simulations, covering a full day, were executed with a stratified model. The effect of stratification was investigated by a comparison with a model continuous in height.
6. TITLE: Water Movement in Layered Soils - A Simulation Model
- AUTHOR: H. van Keulen and C.G.E.M. van Beek
- SOURCE: Department of Theoretical Production Ecology, Agricultural University, Wageningen, the Netherlands or Netherlands Journal of Agricultural Science 19 (1971) Pg 138-153
- SUMMARY: A simulation model for infiltration of water in layered soils, written in CSMP (Continuous System Modeling Program) is described.
- The influence of the occurrence of a compacted layer or a loosened topsoil on the infiltration behavior is checked. It is concluded that this behavior can be predicted if soil parameters are available.
- In an appendix special attention is paid to the problem of choosing the proper size of the compartments in which the soil is divided and the necessary averaging procedure.
- At last the magnitude of the time steps is discussed.



AGRICULTURE/FORESTRY MODELS (Continued)

7. TITLE: The Utility of a Digital Simulation Language for Ecological Modeling
- AUTHOR: R. D. Brennan, C. T. de Wit, W. A. Williams, and E. V. Quatrin
- SOURCE: Oecologia (Berl.) 4 (1970) pg 113-132
- ABSTRACT: Dynamic modeling of ecological phenomena has been greatly facilitated by the recent development of continuous system simulator programs. This paper illustrates the application of one of these programs, S/360 Continuous System Modeling Program (S/360 CSMP), to four systems of graduated complexity. The first is a two species system, with one feeding on the other, using differential equations with constant coefficients. The second and third systems involve two competing plant species in which the coefficients of the differential equations are varying with time. The final example considers the management of a postulated buffalo herd in which the dynamics of the herd population and composition by sex and age is combined with various strategies to control its size and to optimize buffalo production.
8. TITLE: Light Relations in Plant Canopies
- AUTHOR: S. B. Idso and C. T. de Wit
- SOURCE: Applied Optics, Vol. 9, pg 177, January 1970
- ABSTRACT: A theory of light relations in plant canopies is presented which has potential applications in remote sensing and photosynthetic modeling of plant canopies. Predictions of the model are compared with field measurements of light reflection and transmission in a corn crop. Both reflection at the top of the canopy and transmission at the bottom are predicted within one percent of the measured values. Profiles connecting these upper and lower limits are equally well approximated. Variations in the predictions with altitude angle of the sun are confirmed by the observation of several investigators.
9. TITLE: A Holocoenotic Analysis of Environment-Plant Relationships
- AUTHOR: Sherwood B. Idso
- SOURCE: U. S. Water Conservation Laboratory, 4331 East Broadway, Phoenix, Arizona 85040, Technical Bulletin 264
- ABSTRACT: A method is presented for the calculation of net crop photosynthesis, which will, as a result of the calculations involved, also give the rates of latent and sensible heat transfer from the crop. The first step of this analysis will be to determine the factors having direct meaning for the processes of net photosynthate production, transpiration, and sensible heat exchange. Then the mechanics

# AGRICULTURE/FORESTRY MODELS (Continued)

of specifying values of these factors in light of all the interrelationships among the many environmental parameters will be presented. Finally, the calculated values of these factors will be used to determine the rates of the processes in question, namely, net photosynthesis, transpiration, and sensible heat exchange.

10. TITLE: A New Competition Model for Individual Trees  
AUTHOR: I. E. Bella  
SOURCE: Forest Science 17:364-372  
ABSTRACT: The model represents mathematically competitive interaction between individual trees. It consists of two basic components: (1) the influence zone of each tree (which is a function of its size) and (2) the amount and nature of interaction (which depends on the distance between and relative size of the competing tree and its competitors and also on a power of relative tree sizes). Optimum model parameters were obtained by iterative procedures on a computer, combined with regression analyses for pure, even-aged, fully stocked stands of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), jack pine (*Pinus banksiana* Lamb.), red pine (*P. resinosa* Ait.), and aspen (*Populus tremuloides* Michx.) and for an even-aged stand of *Eucalyptus* spp. growing at a range of stand densities. The model satisfactorily described competition effect for the five stands studied and accounted for a greater portion of variation in tree growth than some of the earlier competition indices.
11. TITLE: A Model for a Small Forest Fire ... to Simulate Burned and Burning Areas for Use in a Detection Model  
AUTHOR: P. H. Kourtz and W. G. O'Regan  
SOURCE: Forest Science 17:163-169  
ABSTRACT: A computer-based model of a small smouldering or creeping forest fire has been designed to simulate burned and burning areas of a fire at any time after ignition. The model assumes that a fire spreads in a grid whose squares are homogeneous fuel types. The arrangement of fuel types within each grid for a specific cover is determined by a probability distribution and a Monte Carlo sampling procedure. Rates-of-spread of fire in each fuel type vary with changes in fuel moisture. Persistence time of fire in each fuel type is considered. The minimum time required for the fire to reach any square in the fuel grid is determined by a dynamic programming algorithm. Rates of spread are allowed to vary during the life of the fire.

AGRICULTURE/FORESTRY MODELS (Continued)

12. TITLE: The Simultaneous Determination of Optimal Thinning Schedule and Rotation for an Even-Aged Forest
- AUTHOR: Gerard F. Schreuder
- SOURCE: Forest Science 17:333-339
- ABSTRACT: A model to determine simultaneously the optimal thinning schedule and rotation is presented in two forms. If time is assumed to be continuous, the problem can be formulated in the calculus of variation form. In this form no closed form solution has been obtained. If the model is recast in dynamic programming form, a numeric solution can easily be obtained, without imposing any limitations on the form of the relevant revenue and cost functions. Thus the traditional Faustmann formula is generalized considerably. At the same time the close connection between the calculus of variations and dynamic programming is illustrated.
13. TITLE: Simulation of the Microclimate in a Forest
- AUTHOR: Paul E. Waggoner, G. M. Furnival, W. E. Reifsnyder
- SOURCE: Forest Science, Vol 15, No. 1, 1969
- ABSTRACT: A model of the energy exchange within a canopy of leaves is presented in terms of three sets of equations. The sums of radiant, sensible, and latent heat exchange in several strata of the canopy are set equal to zero. Next, the potentials for the exchange of latent and sensible heat are related to the warming of the leaves. Finally, the difference in potential between adjacent strata are related to the diffusive resistances of the air within the canopy, the boundary layer, and the stomata, and to the fluxes of latent and sensible heat. This system of simultaneous linear equations is solved algebraically for the exchange of latent and sensible heat by each stratum of the canopy, for the leaf temperature of these strata, for the exchange of latent and sensible heat by the soil, and for the storage of heat within the soil. The temperature and humidity above and below the canopy, the absorption of radiation within the canopy, and the several diffusive resistances must be specified. Observations of the exchange of energy and the microclimate within a pine canopy are mimicked by the model. Nine strata are demonstrated to be an adequate number. Calculations with the model explain the effect of stomatal changes upon the evaporation from a forest.

AGRICULTURE/FORESTRY MODELS (Continued)

14. TITLE: Sapling Stand Development: A Compound Exponential Process  
AUTHOR: William B. Leak  
SOURCE: Forest Science 16: 177-180  
ABSTRACT: The development of an even-aged stand during the sapling stage is expressed as a theoretical stochastic model referred to as the compound exponential process. Given a suitable estimate of the one parameter of the process, we can predict the probabilities and expectations of future numbers of trees by diameter classes. The process appears to have interesting applications to the problem of evaluating the future stocking of regeneration or sapling stands.
15. TITLE: Programming Models of Interdependence Along Agricultural Sectors and Spatial Allocation of Crop Production  
AUTHOR: Heady, E. O., Egbert, A. C.  
SOURCE: Journal of Regional Science 4(2), 1-20  
ABSTRACT: A regional programming analysis is presented which deals with over capacity in the agricultural sector. The study aims to measure the total acreage and the interregional specialization of crop production which conforms respectively with specified national demand restraints and apparent changes in production possibilities or comparative advantages among regions. Three models are employed: the ex post model which is related to the 1954 production period; the ex ante model which attempts to show the consequences of increased use of fertilizer and a shift from horse drawn to tractor equipment; and the production-distribution model which attempts to minimize total costs of production and shipping requirements of 10 consumptive regions.
16. TITLE: A Test of a Linear Programming Model of Agriculture  
AUTHOR: Howes, R.  
SOURCE: Regional Science Association Papers, 19, 123-140  
ABSTRACT: An interregional linear programming model was tested in an effort to develop a model which could specify economically feasible water resource investments in the Susquehanna River Basin. The use of such a model of this type could provide simultaneous estimates of benefits resulting from a project and market prices. It could also provide a technique by which the minimum benefit-cost ratio could be considered as a constraining factor.

AGRICULTURE/FORESTRY MODELS (Continued)

17. TITLE: A Grassland Ecosystem Model  
 AUTHOR: L. J. Bledsoe, R. C. Francis, G. L. Swartzman, and J. D. Gustafson  
 SOURCE: Technical Report #64, Grassland Biome, USAOE Natural Resources Ecology Laboratory, Colorado State University, Fort Collins, Colorado  
 ABSTRACT: Describes a complex systems model for a grassland ecosystem. Mechanistic functions were developed for plants, animals, decomposer as well as abiotic elements of the ecosystem. Although preliminary, this is the most comprehensive ecosystem model developed to date.
18. TITLE: Terrestrial Nutrient Cycles in Relation to Soils and Land Use  
 AUTHOR: J. R. Boyle, D. R. Keeney, and M. L. Northup  
 SOURCE: International Biological Program, Eastern Deciduous Forest Biome Memo Report 71-50  
 ABSTRACT: Discusses conceptual model for nutrient cycling.
19. TITLE: A Model of a Carbon Assimilation and Growth in a Grass Plant  
 AUTHOR: N. R. Brockington and G.J.A. Ryle  
 SOURCE: International Biological Program, Eastern Deciduous Forest Biome Memo Report 71-25  
 ABSTRACT: Simulation model of grass which deals with photosynthate produced by each leaf separately and allocates net photosynthate to respiration and growth at various meristem tissues. Model is described briefly.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

20. TITLE: A Guide to the Mathematical Modeling of an Ecosystem  
 AUTHOR: A. B. Clyner and L. J. Bledsoe  
 SOURCE: Part of R. G. Wright, G. M. Van Dyne (Eds.), Simulation and Analysis of Dynamics of a Semi-Desert Grassland, Science Series #6, Range Science Department, Colorado State University, Fort Collins, Colorado  
 ABSTRACT: Good development of the concept of hierarchy of models. Sets specifications for a model and suggests functions for some aspects of ecosystem dynamics.

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AGRICULTURE/FOREST MODELS (Continued)

21. TITLE: POPSID, A Fortran IV Program for Deterministic Population Studies  
AUTHOR: Dean, F. C.  
SOURCE: ORNL-IBP-71-11, Oak Ridge National Laboratory, Oak Ridge, Tennessee  
ABSTRACT: The report describes a program designed to simulate and study population dynamics of an animal population. Input includes age specific fecundity and mortality and has specific provisions for density-dependent mortality.

22. TITLE: SIMCOT, A Simulator of Cotton Growth and Yield  
AUTHOR: W. G. Duncan  
SOURCE: International Biological Program, Eastern Deciduous Forest Biome Memo Report 71-37  
ABSTRACT: Brief verbal description of a simulation model for photosynthesis and growth in cotton.

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23. TITLE: Agricultural Runoff: A Bibliography  
AUTHOR: USDI Office of Water Resources Research  
SOURCE: WRSIC 72-204, Jan 1972 (248) abstract only  
ABSTRACT: Bibliography lists 155 references on agricultural runoff chosen from 35,675 selected water resources abstracts. Significant descriptor index and permuted index are included.

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24. TITLE: Simulation of Grazing Systems  
AUTHOR: Goodall, D. W.  
SOURCE: Part of Jamison, D. A. (Ed.), Modeling and Systems Analysis in Range Science, Science Series #5, Range Science Department, Colorado State University, Fort Collins, Colorado  
ABSTRACT: Describes a simulation model for the management of sheep. An appendix describes the mathematical functions used in the model.

AGRICULTURE/FOREST MODELS (Continued)

25. TITLE: Space-Time Considerations in Modeling the Development of Vegetation
- AUTHOR: R. A. Goldstein and J. B. Mankin
- SOURCE: International Biological Program, Eastern Deciduous Forest Biome, Memo Report 71-138
- ABSTRACT: Contains an excellent discussion of the interrelationship between space and time resolution in ecological modeling. Discusses three levels for studying primary production and the differences in scale needed for each. Also represents a photosynthesis model for a single leaf surface and discusses the general behavior of the model.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

26. TITLE: Basic Concepts in Mathematical Modeling of Grassland Ecosystems
- AUTHOR: D. A. Jameson
- SOURCE: Part of D. A. Jameson (Ed.), Modeling and Systems Analysis in Range Science, Science Series #5, Range Science Department, Colorado State University, Fort Collins, Colorado
- ABSTRACT: Good general coverage of the basics of modeling and its use in a research effort.

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27. TITLE: A Finite Difference Model for Simulation of Dynamic Processes in Ecosystems
- AUTHOR: R. R. Lassiter and D. W. Hayne
- SOURCE: Part of B. C. Patten (Ed.), Systems Analysis and Simulation in Ecology, Vol 1., Academic Press, New York, pg. 367-400
- ABSTRACT: Lassiter and Hayne present an excellent and well documented derivation of a model for a generalized animal population, including both changes in numbers and energy balances. Several populations are considered together to yield a model for a simple ecosystem.

AGRICULTURE/FOREST MODELS (Continued)

28. TITLE: The Sun's Work is a Cornfield  
AUTHOR: E. Lemon, D. W. Stewart and R. W. Shavcroft  
SOURCE: Science 174, 371-378  
ABSTRACT: Describes the plant-atmosphere-soil model (SPAM) developed for investigating questions about the growth of corn. The structure of the model is explained which emphasizes the vertical distribution of independent variables and the resulting plant growth. Model predictions of some parameters seem quite accurate, but vertical diffusivity and some plant parameters are less adequately predicted. The model appears to be limited at present by the lack of adequate understanding and theory in some areas.
29. TITLE: Models for Interplant Competition in Irregularly Distributed Populations  
AUTHOR: R. Mead  
SOURCE: Part of G. P. Patil, C. Pielou, and W. F. Waters (Eds.), Statistical Ecology, Vol 2, Sampling and Modeling Biological Populations and Population Dynamics, Penn. State Univ. Press, University Park, Penn., 420 pg.  
ABSTRACT: Some work on plant competition is reviewed which follows up competition models based on plant polygon--correlation with size of plants that share a side of the polygon with the plant. He discusses problem of interpreting the numerical competition parameter in biological terms.
30. TITLE: An Example of Optimization Techniques in Land Management, the Resource Allocation Model  
AUTHOR: F. E. Price  
SOURCE: Part of D. A. Jameson (Ed.), Modeling and Systems Analysis in Range Science, Science Series #5, Range Science Department, Colorado State University, Fort Collins, Colorado  
ABSTRACT: Linear programming applied to forest management.
31. TITLE: Taeda 1, A Model of Loblolly Pine Growth  
AUTHOR: C. E. Murphy and J. D. Hesketh  
SOURCE: International Biological Program, Eastern Deciduous Forest Biome Memo Report 71-34  
ABSTRACT: Presents an initial conceptual model for pine growth. Discusses data being gathered on the system and how these will be formulated into the model.



AGRICULTURE/FOREST MODELS (Continued)

32. TITLE: Water Resource Management in Arid Environments  
 AUTHOR: R. G. Cummings, Resources for the Future Washington, D. C. and D. L. Winkleman, Iowa State Univ., Ames, Iowa  
 SOURCE: Water Resources Research, Dec. 1970. V6, n6, pg 2559 (10) research report  
 ABSTRACT: The author formulates a model of agricultural production based on water resources in which the benefits derived are optimized. Variables considered are: water and expected water receipts are related to optimum pattern of land use and production; intertemporal allocation of water and rate of investment for water distribution. The optimum rate of investment is determined by equating marginal investment costs with present value of future production attributable to savings in distribution losses.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

33. TITLE: Simulation Models in Forest Management and Harvesting  
 AUTHOR: R. M. Newnham  
 SOURCE: The Forestry Chronicle, 44,7-13  
 ABSTRACT: The advantages and disadvantages of simulation models are described and examples are given of their use in forestry. Stand models and a simulation model for pulpwood harvesting machines are described in some detail. Stand models simulate the growth of a stand on an individual tree basis and can be used for testing the effect of the different silvicultural operations on subsequent stand development. The harvesting simulation models imitate the passage of a harvesting machine through a stand of pulpwood. They can be used to test the effect on harvesting time of using machines of different sizes and operating characteristics. The effect of stand structure on harvesting time can also be tested.

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34. TITLE: A Linear Programming Model for Forest Production Control at the AEC Oak Ridge Reservation.  
 AUTHOR: E. L. Norman and J. W. Curlin  
 SOURCE: Oak Ridge Nat. Lab. ORNL-4349, Oak Ridge, Tennessee  
 ABSTRACT: The model selects among management alternatives to maximize the value of the residual stand over one cutting period of twelve years discounted to the present. Constraints included a minimum annual income, minimum volume to be cut

AGRICULTURE/FOREST MODELS (Continued)

from a given stand, maximum volume to be cut from all stands. Volumes, growth, tree condition classes, tree grade, stumpage values, cutting alternatives, and site index are variables in either the multiple regression equations for growth or the linear programming model.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

35. TITLE: Remote Sensing of Terrestrial Vegetation: A Comprehensive Bibliography  
AUTHOR: P. F. Krumpe, Graduate Program in Ecology  
SOURCE: University of Tennessee, Knoxville, Tennessee 37916  
BRIEF DESCRIPTION:

As a consequence of the NASA: ERTS, and SKYLAB programs, as well as other projects, future theoretical, technical, and applied contributions to remote sensing should prove enormous. Based on this assumption, the author decided to accumulate and synthesize pertinent remote sensing reference materials directly associated with, and allied to, the study of terrestrial vegetation.

By comparison, contributions in agriculture, forestry, and ecology presently constitute the main portion of total available remote sensing literature.

This privately supported comprehensive bibliography contains greater than 850 references dealing with the utilization and application of remote sensing in forestry, agriculture, and plant ecology, as well as closely allied fields, such as land-use planning, resource inventory and management, and soils and terrain analysis. In addition, technical background, historical, and data manipulation and analysis references are included.

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36. TITLE: The Mathematical Representation of Migration  
AUTHOR: F. W. Preston  
SOURCE: Ecology 47(3): 375-392  
ABSTRACT: Proposes an equation to model the numbers of migrating birds passing a point as a function of X-the time of year, B-the interval between migration peaks, M-the average tightness (shortness of span in days) or standard deviation of the spring and fall migrations, and K-the difference in tightness between spring and fall migrations. Existing data on migration are examined in light of this model and some of the consequences considered.

AGRICULTURE/FOREST MODELS (Continued)

37. TITLE: A Matrix Model for Forest Management  
 AUTHOR: M. B. Usher  
 SOURCE: Biometrics 25(2): 309-315  
 ABSTRACT: A mathematical model which has a unique biologically meaningful solution is developed for the management of renewable resources. Data for a Scots-pine forest are given. The model uses matrix notations and computer oriented numerical techniques are suggested to find the solution.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

38. TITLE: Analytical Hydrography in Watershed Engineering Bibliographies and Abstract  
 AUTHOR: U. S. Department of Agriculture, Hydrograph Laboratory  
 SOURCE: USDA Hydrograph Laboratory, Room 139, Soils Building, Plant Industry Station, Beltsville, Maryland 20705  
 BRIEF DESCRIPTION:

The report contains abstracts of publications of the USDA Hydrogen Laboratory under five subject matter headings;  
 (1) Meteorology and Climatology (2) Hydrodynamics (3) Soils and Vegetation (4) Hydrogeology (5) Systems Analysis

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\* \* \* \* \* NON-MODEL \* \* \* \* \*

39. TITLE: Modeling Abstracts, Vol. I, No. 1  
 AUTHOR: R. V. O'Neill and N. Ferguson  
 SOURCE: Memo Report No. 72-37  
 Eastern Deciduous Forest Biome Information Center  
 Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830

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AGRICULTURE/FOREST MODELS (Continued)

40. TITLE: Dynamic Programming for Deer Management Planning  
 AUTHOR: L. S. Davis  
 SOURCE: Journal of Wildlife Management 31(4): 667-679  
 ABSTRACT: A mathematical model utilizing a simultaneous solution of equations to find the optimum level of deer numbers and the optimum level of clearcutting timber, etc. to best manage a tract of forest land for both timber and deer (both hunting and seeing) with the setting of maximum and minimum values for worthwhile deer management.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

41. TITLE: Selected Bibliography on the Modeling and Control of Plant Processes, 1972  
 AUTHOR: M. M. Viswanathan and P. M. Julich  
 SOURCE: Department of Electrical Engineering, Louisiana State Univ., Baton Rouge, La. 70803  
 ABSTRACT: A bibliography of information pertinent to the problem of simulating plants is presented. Detailed simulations of constituent pieces are necessary to justify simple models which may be used for analysis. Thus, this area of study is necessary to support the earth resources program. The report sums up the present state of the problem of simulating vegetation.

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42. TITLE: Simulation of the Temperature, Humidity, and Evaporation Profiles in a Leaf Canopy  
 AUTHOR: P. G. Waggoner and W. E. Reifsnyder  
 SOURCE: Journal of Applied Meteorology 7(3):400-409  
 ABSTRACT: The model presented synthesizes profiles of temperature, humidity, and evaporation in a canopy of leaves from meteorological conditions at canopy top, from the temperature and humidity at the soil surface, from a leaf dimension, from the vertical distribution of leaf area and stomatal resistance, and from observations or extinction coefficients for ventilation and radiation within the canopy under steady-state conditions. Simulation was given in the cases of past data on red clover and barley canopies.

AGRICULTURE/FOREST MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

43. TITLE: A Partial Annotated Bibliography of Mathematical Models in Ecology  
AUTHOR: John A. Kadlec, Principal Investigator  
SOURCE: Analysis of Ecosystems Program, International Biological Program, University of Michigan, School of Natural Resources, Ann Arbor, Michigan  
DESCRIPTION: The report contains 621 abstracts of literature examined by the Analysis of Ecosystems Program group during the summer of 1970 and supported by a National Science Foundation grant. The abstracts cover literature in the fields of Biology, Hydrology, Soils, Meteorology, and Ecology.

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44. TITLE: Economic Model Building and Computers in Forestry Research  
AUTHOR: D. E. Chapelle  
SOURCE: Journal of Forestry Vol. 64, No. 5, Pg 329-333  
DESCRIPTION: General introduction to the use of various types of models in economics of forest management.

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45. TITLE: Current Generalized Computer Programs Used in Grassland Biome Analyses  
AUTHOR: D. M. Swift, Coordinator  
SOURCE: Technical Report No. 34, Grassland Biome, U. S. International Biological Program, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado 80521  
DESCRIPTION: This report deals with the functioning programs which are available at the Natural Resource Ecology Laboratory at CSU and have been useful in the IBP Grasslands Biome activities. These include generalized statistical programs as well as generalized mathematical programs such as routines for solving differential equations.

## AGRICULTURE/FOREST MODELS (Continued)

All programs are described in general terms so that investigators not familiar with programming may evaluate their utility to various types of data. Those programs which are not frequently used or which are deemed most useful to the field investigator or the modeler are discussed in some detail. The reader will note that most of the programs can be set up and run very simply by merely adding a few control cards and a data deck to the source deck. Others, however, require a user-supplied subroutine, which presupposes that the potential user have a knowledge of FORTRAN programming. FORTRAN listings are included for these programs unless such listings are readily obtainable from some other source.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

46. TITLE: Resource Information and Planning Systems: A Catalog of Computerized Systems in the U. S. Forest Service
- AUTHOR: C. Row and B. Schmelling
- SOURCE: Forest Service, U. S. Department of Agriculture, Washington, D. C. 20250
- ABSTRACT: This catalog of major resource-related computerized systems was originally prepared to help the Washington Office Advisory Staff in their study of needs for coordination of resource information systems. It soon became obvious that it made little sense to study resource information systems without considering the planning functions and types of decisions for which resource information is needed. Thus the inquiry was broadened to include five types of systems:
1. Resource information collection and analysis systems.
  2. Information storage, retrieval, and display systems.
  3. Resource response simulation systems.
  4. Resource facility design and operation planning systems.
  5. Multiple-use and environmental planning and decision systems.

Each type of system is discussed briefly at the beginning of the catalog section.

Criteria for inclusion in this catalog were deliberately broad. The main qualifications for each entry were that it had to be:

AGRICULTURE/FOREST MODELS (Continued)

1. A "system" or a major component of a system for resource information, simulation, or planning. A system, as used here, is simply a set of regularly interacting or interdependent groups of processes organized to achieve a desired result.
2. Related primarily to resource analysis, simulation, or planning. A number of systems thought to be primarily administrative in nature are listed in the last section rather than being described in detail. Resource systems are those which are directly related to the inventory simulation or planning of natural resources in their on-the-ground condition. In contrast, resource-related administrative systems are involved with the operational, administrative, and business management phases of resource management. For example, a system that measures the volume and growth of timber on a given area of land is a resource system. One that reports the timber volumes to be cut or types and numbers of range improvements are administrative systems. Several of the systems in this catalog serve both function.
3. Developed or being adapted for operational use by the Forest Service. Some programs developed by research units have been developed primarily to explain phenomena, and have not been intended for continued use. Several systems, such as a OPT-LOC (Optimal Location) and GAPAS (General Agricultural Production Analytic System) were not originally developed by the Forest Service, but are being adapted for its use. No attempt was made to include numerous similar programs developed by other agencies and firms, or developed primarily for training purposes.
4. Computerized either partially or completely. The complexity, versatility, and flexibility of the computer programs in these systems vary widely. In some cases initial recording or digitizing of observed data has also been automated. Each system, however, has been cross-referenced to the Computer Application Inventory Document Numbers of the Service-Wide Computer Systems Study.

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AGRICULTURE/FOREST MODELS (Continued)

47. TITLE: Some Concepts of Modeling
- AUTHOR: Gordon Swartzman, Coordinator
- SOURCE: Technical Report No. 32, Grassland Biome,  
U. S. International Biological Program,  
Natural Resource Ecological Laboratory,  
Colorado State University,  
Fort Collins, Colorado 80521
- ABSTRACT: This document gives a brief review of the general kinds of models available to and used by ecologists in considering either segments of or entire ecosystems. In many instances the models have been applied in management of renewable resources and some examples come from that area. It does not include a thorough review of all the analytical procedures available.



APPENDIX D

URBANIZATION MODELS

1. TITLE: Regional Environmental Systems Analysis (RESA) Land Use Simulation Model

AUTHOR: Oak Ridge National Laboratory, Regional Environmental Systems Analysis Group

SOURCE: Oak Ridge National Laboratory, RESA Group, Oak Ridge, Tennessee

OBJECTIVE/  
PURPOSE:

1. To spatially distribute new or changing increments of population and employment in the form of land-use activities.
2. To test policy decision variables such as comprehensive plans, transportation proposals, and siting specific activities followed by a spatial testing of the effect before implementation.
3. To provide feedback information to the socio-economic, ecological, and political sectors of the comprehensive model.

REFERENCE: 1. ORNL-4632

Oak Ridge National Laboratory - National Science Foundation Interdisciplinary Research Relevant to Problems of our Society Progress Report of Summer Study, Dec. 1970

2. ORNL-NSF-EP-3

The Environment and Technology Assessment Progress Report-June - Dec. 1970, Feb. 1971

3. New Tools for Regional Planning - AIA Journal, C. R. Meyers, Jr. October 1971

4. ORNL-NSF-EP-25

Computer Display in Spatial Modeling, A. H. Voelker, C. R. Meyers, Jr. August 1972

5. ORNL-NSF-EP-7

Regional Modeling Abstracts, Vol. 1, C. R. Meyers, Jr. October 1971

6. ORNL-NSF-EP-10

Regional Modeling Abstracts, Vol. 2 C. R. Meyers, Jr. December 1971

7. ORNL-NSF-EP-23

Regional Modeling Abstracts, Vol. 3, C. R. Meyers, Jr. June 1972

# URBANIZATION MODELS (Continued)

8. Model Data Acquisition & Display, RESA Memo Report #72-3 by A. H. Voelker, C. R. Meyers, Jr., D. L. Wilson, & T. C. Tucker, October 1972

STATUS: September 15, 1972

1. Comprehensive data base including: Spatial cultural, and landscape characteristics with corresponding tabular information related to the spatial unit assignments.
2. Initial operational computer information system (Phase I, Oak Ridge Regional Modeling Informatio System, ORRMIS).
3. Operational programs for initial 30-second allocation indices.
4. Operational subregional selection process.

INPUT:

1. Socio-economic projections: (by total 6500 square mile region)
  - . Regional employment projections.
  - . Regional account of the number of businesses in each employment category.
  - . Regional population projections (by age and family categories).
2. Environmental (by 30-second cell approximately 170 acres).
  - . Status of air and water pollution levels.
3. Land Use (by 30-second: 15-second, approximately 40 acres; and 3.75 seconds, approximately 2 1/2 acres) cells.
  - . Existing (starting) spatial land-use configuration.
  - . Initial allocation indices scores.
  - . ORRMIS spatial data base.

REGIONAL

LOCATION: Knoxville, Tennessee and its surrounding sphere of regional influence (corresponding political boundaries--East Tennessee Development District (ETDD); East Tennessee).

URBANIZATION MODELS (Continued)

2. TITLE: Empiric Activity Allocation Model  
AUTHOR: Peat, Marwick, Mitchell and Co.  
1025 Connecticut Avenue, N. W.  
Washington, D. C.  
SOURCE: Department of Regional Planning  
Metropolitan Washington Council of Governments  
Washington, D. C.  
ABSTRACT: The "Empiric" Model is designed to allocate projected regional population, employment, and land-use growth between a set of smaller sub-regions or districts. The model is designed to perform three specific functions: (1) to generate small-area forecasts of population, employment and land-use, based on exogenously specified regional totals and exogenously specified planning policies, (2) to evaluate the impact of alternative public and private planning policy decisions on the future distribution of regional activity, (3) to serve as a mechanism for analyzing, interrelating, and coordinating future public policy decisions.
3. TITLE: A Regional Economic Simulation Model  
AUTHOR: Southeastern Wisconsin Regional Planning Commission  
SOURCE: Technical Report No. 5  
Southeastern Wisconsin Regional Planning Commission  
Waukesha, Wisconsin  
ABSTRACT: The Regional Economic Simulation Model was developed and applied as part of the Regional Land Use-Transportation Study of the Southeastern Wisconsin Regional Planning Commission. The function of the model is to provide a series of regional employment and population forecasts required as inputs to the land use-transportation planning sequence. The model also allows for the dynamic analysis of inter-industry relationships for the regional economy. Difference equations are used to simulate inter-industry relationships over time. This introduction of the dynamic dimension of time differentiates this model from most input-output models developed in the past, which have been static in nature.  
  
Primary data obtained from small samples of firms in various industries were used in preparing parameter estimates for the model. These primary data were supplemented by state corporate tax and employment records and other secondary sources, such as the U. S. Department of Commerce input-output tables.

## URBANIZATION MODELS (Continued)

Historical simulation tests were conducted over the 1946-1960 period. Comparisons of model outputs with historical data indicated an error of 2.99 percent in the overall employment level forecast by the model for 1960 from 1946 initial conditions, when that level was compared with actual 1960 employment levels. Errors in major industry component forecasts ranged from 0.8 percent in manufacturing to 19.6 percent in private services and education. Future employment levels were forecast for the 1970-1990 period using the simulation model. These forecasts were somewhat higher than those developed using non-model techniques developed and applied by the Commission.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

4. TITLE: The Application of Remote Sensing Techniques to Inter and Intra Urban Analysis: Final Report

AUTHOR: Dr. Frank E. Horton

SOURCE: Institute of Urban and Regional Research  
102 Church Street  
University of Iowa, Iowa City, Iowa 52240

REPORT  
OUTLINE: The report deals with remote sensing inputs to the general problem of obtaining data of utility for urban planning, management, and research. It presents a conceptual structure and outline of an urban information system. It addresses the problem on how to integrate remote sensing data with conventionally collected information in a system that describes and reports urban change and discusses user requirements, data compatibility, spatial referencing, and imagery utilization. Washington, D. C. is used as a study area in comparing imagery derived land use information with conventionally collected data.

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\* \* \* \* \* NON-MODEL \* \* \* \* \*

5. TITLE: The Construction of an Urban Growth Model

AUTHOR: D. R. Seidman

SOURCE: Delaware Valley Regional Planning Commission  
Plan Report No. 1 (1969)  
Philadelphia, Penn.

DESCRIPTION: A detailed discussion, often technical, of the seven models developed by the Delaware Valley Regional Planning Commission for Philadelphia.

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# URBANIZATION MODELS (Continued)

6. TITLE: A Time-Oriented Metropolitan Model for Spatial Location  
 AUTHOR: Consad Research Corporation  
 SOURCE: Consad Research Corporation, Department of City Planning, Pittsburgh, Pennsylvania, Technical Bulletin No. 6 (1964)  
 ABSTRACT: A description of the proposed revision and adaption of the Lowry model is given. The formulations could be used in that part of the Pittsburgh urban renewal simulation model which is devoted to the allocation of residential and commercial land use. The proposed revisions try to alter the Lowry model by being cognizant of three special needs of a simulation model for land use allocation in the City of Pittsburgh. These needs are for a time-orientated model, differentiation of households by income, housing characteristics, social characteristics, or all three, and limitation of the simulation study to locational characteristics within the City's boundaries.

7. TITLE: A Probabilistic Model for Residential Growth  
 AUTHOR: T. G. Donnelly, E. S. Chapin, and S. F. Weiss  
 SOURCE: Institute for Research in Social Science, University of North Carolina (1964), Chapel Hill, N. C.  
 ABSTRACT: Experimental tests in the use of a synthetic model for simulating the process of residential development outlined in an earlier work are reported. The model is part of a linked system of models which is proposed for simulating the growth and development of a metropolitan area. This particular model asks the question - given a forecast of the total number of households which will be settling in a particular metropolitan area and given certain key development decisions and policy positions of local government, what pattern of residential development is likely to emerge. The research problem consists of developing a prototype form a probabilistic type model proposed earlier and designing a machine routine economical for carrying out multiple simulations of the kind required in this type of approach.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

8. TITLE: Models of Urban Land-Use Development  
 AUTHOR: Leslie J. King  
 SOURCE: Battelle, Columbus Laboratories, 505 King Ave., Columbus, Ohio 43201  
 ABSTRACT: The report is intended to provide a background on land-use modeling techniques and recommendations for small metropolitan areas contemplating use of these models. Emphasis is placed on those land-use studies and models that are essentially positive in their approach, that is,

## URBANIZATION MODELS (Continued)

those that deal mainly with explanations of what has happened in urban land-use patterns and with the prediction of future developments consistent with these explanations or understandings. An annotated bibliography on land-use modeling techniques is appended to this report.

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9. TITLE: A Model of Metropolis  
AUTHOR: I. S. Lowry  
SOURCE: Memorandum RM-4035-RC, Pittsburgh Regional Planning Association and the Rand Corporation (1964), Santa Monica, California  
ABSTRACT: A computer model of the spatial organization of human activities within a metropolitan area is described. The model is intended for eventual use as a device for evaluating the impact of public decisions (e.g., concerning urban renewal, tax policies, land-use controls, transportation investments) on metropolitan form, and a device for predicting changes in metropolitan form which follow over time as a consequence of currently visible or anticipated changes in key variables such as the pattern of basic employment, the efficiency of the transportation system, or the growth of population. The development of the model to the stage at which it becomes a practical tool for planning and decision-making will require more time and effort. This first-generation model has been fitted to data for Pittsburgh, Pennsylvania, and enough experimental computer-runs have been completed to allow an appraisal of the practicability of the approach, and to indicate the strong and weak points of the model and also of the available data. The findings reported here offer guidance both to the development of a second-generation model and to data-collection programs. As examples of the eventual usefulness of model-oriented analysis of metropolitan form, the fitted models quasi-predictions of the merging spatial structure of Pittsburgh is discussed.
10. TITLE: A Report on an Urban Transportation Model, Some Progress and Some Problems  
AUTHOR: J. F. Kain  
SOURCE: Rand Corporation, Santa Monica, California

# URBANIZATION MODELS (Continued)

ABSTRACT: The model is intended as a vehicle for evaluating the general underlying technological and economic changes occurring in today's urban areas. The main concern is with urban transportation systems of metropolitan scale. Initial model-building efforts were directed towards construction of the non-residential land-use and employment and the household behavior submodels. Fairly extensive research was carried out in four employment location sub-studies; central-office-location; location of government employment and land use, changes in the location of employment in manufacturing, wholesaling, retailing, and selected service trades; and non-residential construction activity in metropolitan areas.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

11. TITLE: Urbanization and Sedimentation: A Bibliography  
AUTHOR: USDI Office of Water Resources Research  
SOURCE: WRSIC 71-203 October 1971 (116) abstract only  
ABSTRACT: Bibliography lists 100 reference works on urbanization and sedimentation chosen from 31,244 selected water resources abstracts. A permuted index is included.

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12. TITLE: Vancouver Regional Simulation Study 1970-1971  
AUTHOR: M. A. Goldberg, C. S. Holling, and R. F. Kelly  
SOURCE: Resource Science Center, the University of British Columbia, Vancouver 8, Canada  
ABSTRACT: A model is being developed of man/environment interaction in the lower mainland of British Columbia, which can test the consequences of alternative policies. The progress is reported of groups dealing with: population and demographic submodel: economic submodel: transportation model: land use models: health systems: pollution: human ecology: land classification: data management: and resources and public services.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

13. TITLE: A Short Course in Model Design  
AUTHOR: I. S. Lowry  
SOURCE: American Institute of Planners Journal Vol. 31(2) (1965)

## URBANIZATION MODELS (Continued)

**ABSTRACT:** An attempt is made to provide some orientation to the model-builders way of thinking, to interpret the jargon of his trade, and to suggest a few standards for the evaluation of his product. Three major classifications of models are recognized - descriptive, predictive, and planning. Each is briefly described and their use emphasized. The process whereby the model builder selects a theoretical perspective, designs a logical framework large enough to encompass his objectives, postulates the existence of enough empirical regularities to permit the resolution of his problem and fit or calibrate the models is described.

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14. **TITLE:** Urban Performance Model
- AUTHOR:** B. A. Arad
- SOURCE:** Planning Research Corporation, Washington, D. C.
- ABSTRACT:** The UPM allocation model affects incremental changes in cell population by removing and allocating activities, subject to exogenously defined land-use plan and gross regional forecasts. The allocation process uses measures of new opportunity and urban quality of the base year and then removes and allocates small increments of activity based on expected changes in new opportunity and in urban quality assuming "all other things are equal." The criteria for removal of cell activity is the marginal utility. As long as the marginal utility of any activity increases with removal of activity, the activity is expected to be removed from the cell and assume a new position in the urban area. The criteria for allocating activity is also the marginal utility, however, for allocation of activity the supply of land should be considered and a location preference is defined as a function of the utility of locations and the residual holding capacity. The allocation order proceeds along a decreasing rank order of the location preference subject to maintaining non-negative marginal utilities with each small increment of allocation. Following the allocation of the total marginal increment of growth, new opportunity and urban quality values are determined for each location. The effects of the activities in one cell on all other cells and land-uses is accounted for: new transportation matrix for the beginning or the new regional allocation period is assumed to be in effect thereby affecting the values of new opportunity and urban quality of each cell. A new distribution of residents (and other land-use activities) on the new opportunity-urban quality matrix can be described. Applying the urban performance measures the net effects of land-use, the transportation program or any other exogeneous decisions can be determined.



URBANIZATION MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

15. TITLE: A Conceptual Framework for Urban Planning Models  
 AUTHOR: M. Kilbridge, R. O'Block, and P. Teplitz  
 SOURCE: Management Science, 15(6), B-246-B-266  
 ABSTRACT: A framework is presented for the analysis of models which have been designed for, or used in, urban physical and economic planning. The models were distinguished by their basic characteristics, rather than on the basis of their applications. Four basic characteristics are identified: the subject of the model: its function: its underlying theory: and its method. Besides providing a conceptual framework for the analysis and development of urban planning models, this conceptual scheme serves as the basis of a classification scheme which allows the study and comparison of existing models. Such a system is presented as an illustration of the process of model analysis using this conceptual framework.

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16. TITLE: Jobs, People, and Land  
 AUTHOR: Center for Real Estate and Urban Economics  
 SOURCE: Institute of Urban and Regional Development, University of California, Berkeley, California  
 ABSTRACT: A model was developed which could be employed in analyzing the probable impact of change in employment, transportation patterns, and planned programs of urban renewal upon future patterns of urban growth and land use in the San Francisco Bay area. The geographical coverage of the model was extended to include 13 Bay-Delta counties. Forecasts were made of employment, population, housing, and land use for 5-year periods from 1965 to 1990 and for 10-year periods continuing to 2020. Although the basic unit of output in the model is the census tract, the forecasts are summarized by counties.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

17. TITLE: Planning and Forecasting Metropolitan Development  
 AUTHOR: N. A. Irwin and D. Brand  
 SOURCE: Traffic Quarterly, pg. 520-540 (Oct. 1965)

# URBANIZATION MODELS (Continued)

ABSTRACT: A good review of the formulations and sensitivity analyses of the Empiric and Polimetric models developed for Boston. The first involves a set of simultaneous linear equations which predict changes in the subregional shares of located variables. There were seven (including white collar population, blue collar population, retail and wholesale employment, manufacturing employment, other employment, total resident population, and total employment) on the basis of (1) changes in subregional shares of all other located variables in subregions, (2) changes in value of subregional shares of other locator variables. The Polimetric model involves a series of non-linear differential equations which relate changes in the level of subregional activity to the existing level and the in-migrations and out-migrations of activities.

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\* \* \* \* \* NON-MODEL \* \* \* \* \*

18. TITLE: The Present and Futures of Urban Land-Use Models  
 AUTHOR: D. R. Seidman  
 SOURCE: Proceedings, Fourth Annual Conference on Urban Planning Information Systems and Programs, Pg. 119-128 (1966).  
 DESCRIPTION: Begins with review of Delaware Valley RPC activities allocation model which involves seven sub-models for 192 districts in Philadelphia. Models are solved in sequence for series of five-year recursive steps, 1960-1985. Discusses calibration results and forecasting runs. Reviews other land-use models especially with respect to problems of areal aggregation and calibration, and long range versus short range forecasting.

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19. TITLE: A Model for Simulating Residential Development  
 AUTHOR: F. S. Chapin, Jr.  
 SOURCE: Journal of the American Institute of Planners, 31(2)  
 ABSTRACT: This article is the outgrowth of a long period of experimentation with models of residential and other development which focus on the individual decision-maker, the householder in search of a home, and the builder attempting to cater to his desires. The means by which this process is simulated in a computer is described and how this view of

URBANIZATION MODELS (Continued)

consumer behavior has led naturally into a consideration of households activity patterns and into research on these patterns is indicated. The integration of these two approaches may lead in the direction of measurements of accessibility and of taking account of the competition for desirable sites, of consequent increases in the intensity of utilization, and of the rents of these sites. A remarkable convergence is demonstrated between research starting at the level of individual decision units and coming to consider the larger framework, and research starting from gross changes in the metropolitan configuration and coming to give increasing consideration to the actual decision process.

20. TITLE: A Simulation Model for Renewal Programming  
AUTHOR: I. M. Robinson, H. B. Wolfe, and R. L. Barringer  
SOURCE: Journal of the American Institute of Planners, 31 (2)  
ABSTRACT: The simulation model presented here for use in urban renewal planning in San Francisco is particularly notable for the detailed attention it gives to the atomistic decision-making process which leads to changes of occupancy and the state of the housing stock in large cities. The objectives of building the model are discussed in terms of the uses to which it will be put and the simulation of private market decisions and public policy impacts are described in some detail. The absence of any transportation and accessibility considerations is worthy of note. It may be explained in part by the very small geographical extent of San Francisco and in part by the meticulous attention which is given to other aspects of the housing market influencing residential choice.
21. TITLE: The Pittsburgh Urban Renewal Simulation Model  
AUTHOR: W. A. Steger  
SOURCE: Journal of the American Institute of Planners, 31(2)  
ABSTRACT: The model described has its origin in the work of Ira. S. Lowry for the Pittsburgh Region Economic Study. Lowry's pioneering modeling effort was perhaps the first large-scale and relatively complete metropolitan simulation to "go on the air." A new model predicting the location of basic industry now makes the Lowry model a more complete predictor of urban development. The predictions of residential locational choice on the basis of job location, and of the location of commercial activity on the basis of residential location, has been refined in one sense. This prediction is now incremental and hence depends on previous development. This change makes the

## URBANIZATION MODELS (Continued)

model depend upon the pattern of previous development, and renders it more sensitive to policy assumptions, but it no longer reflects, as did Lowry's original model, what might be called in some sense an ideal or equilibrium state of the metropolis. The operation of the complete simulation model, its data requirements, and its relation to the decision processes involved in planning urban renewal for the City of Pittsburgh, are described.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

22. TITLE: Selected Urban Simulations and Games  
 AUTHOR: M. Nagelberg and D. L. Little  
 SOURCE: Institute for the Future, Riverview Center, Middletown, Connecticut  
 ABSTRACT: A number of simulation projects published elsewhere are outlined and a genealogy and chronology of all major urban simulation efforts to date are provided. Many of the models described have never been made fully operational, and those that are still being used are under constant modification. Each model is then actually a series of models, games, or computer programs embodied in some over-all simulation effort. The models are of three basic types: computer simulations: games: and gaming simulations.

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23. TITLE: The Bass V Residential Model: Exposition, Development, Experimentation Critique  
 AUTHOR: C. K. Bernard  
 SOURCE: Graduate School of Business Administration University of California, Berkeley, California, and Center of Real Estate and Urban Economics, University of California, Berkeley, California  
 ABSTRACT: The Bass Model is described in regard to its function and background with a special emphasis on the BASS RESIDENTIAL Model and its application to Marin County transportation planning. The exposition is kept at the conceptual level, although key relationships are given in equation form consistent with the program code. The model process is amplified to demonstrate the theoretical incremental commuter flows implied by the new housing

# URBANIZATION MODELS (Continued)

allocation process. Commuter flow increments are illustrated by drawing examples from the Bass V Sensitivity Model. The development of the Sensitivity Model and the comprehensive sensitivity experiments designed around it are described. Key results are presented and reference is made to the large collection of output data stored on cards and in printout form.

24. TITLE: Open Space and the Urban Growth Process. An Economic Evaluation Using a Growth Allocation Model  
AUTHOR: J. R. Recht and R. J. Harmon  
SOURCE: The Center for Real Estate and Urban Economics, Institute of Urban and Regional Development, University of California, Berkeley, California  
ABSTRACT: A portion of a study undertaken to provide an evaluation of the economic impact of the implementation of an open space preservation for the San Francisco Bay Area is described. The BASS Model was used to simulate the bay area's growth as appears likely under current trends and, alternatively, as it would likely be if an open space program were to be implemented.

\* \* \* \* \* \* \* \* \* NON-MODEL \* \* \* \* \*

25. TITLE: Review of Analytic Techniques for the CRP  
AUTHOR: W. A. Steger  
SOURCE: Journal American Institute of Planners  
ABSTRACT: Existing urban renewal model building, or models, are explored, which have evaluation of urban renewal plans as one of the basic driving forces along with other exogenous events, such as external population and employment factors. The models discussed fall in three categories insofar as their projection phases are concerned: controlled variation of independent variables: simulation forecasting models: and analytic mathematical models.

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URBANIZATION MODELS (Continued)

26. TITLE: A Producer Model for Residential Growth  
 AUTHOR: E. J. Kaiser  
 SOURCE: Center for Urban and Regional Studies Institute for Research in Social Science, University of North Carolina, Chapel Hill, N. C.  
 ABSTRACT: The major elements in developed locational behavior are conceptualized to provide a framework for the examination of producer orientated variables and relationships. A pilot version of a computerized, operational model is suggested to forecast the spatial distribution of residential subdivisions. With the exception of physical characteristics, site characteristics were strongly associated with subdivision location. The impact of developer type on these associations was clearly demonstrated to be significant with the exception of the socio-economic location variable, developer type had a consistently stronger effect than did price range in the univariate associations. Differences in behavior between large and small developers is at least as great as, maybe greater than, the differences in location between price ranges.

\* \* \* \* \* NON MODEL \* \* \* \* \*

27. TITLE: Urban Growth and Development Models: Transition and Prospect  
 AUTHOR: F. E. Horton and J. F. Hultquist  
 SOURCE: Journal of Geography, Feb. 1971, V70, n2, p 73 (11) survey report  
 ABSTRACT: Comprehensive activity allocation models for city planning are examined; contributions of geographers to these endeavors is assessed. The strategies used to handle the various problems in urban modeling are considered in the general case including: equilibrium assumptions, allowance for both growth and decline, and time intervals (or lags) for development cycles. An evolutionary comparison of several models is then presented with an emphasis on spatial properties. Consideration of urban growth and development models by geographers will facilitate the education and training of individuals capable of intelligently approaching alternative decisions and their impact on the quality of urban life.

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URBANIZATION MODELS (Continued)

28. TITLE: New Tools for Regional Planning  
 AUTHOR: C. R. Meyers, Jr.  
 SOURCE: American Institute of Architects Journal, October 1971, 37-40  
 ABSTRACT: Mathematical models have tremendous potential as a regional planning tool. A research effort to develop a modeling methodology and to build and test a comprehensive regional model is presently underway at the Oak Ridge National Laboratory. The model that resulted from the initial effort was a county model made up of a series of linked submodels which recognized a division of the human ecosystem into four general categories: physical factors: biological-ecological factors: sociocultural factors: and economic factors. Each submodel is part of the interconnected model linked to the user through an iterative loop. The user enters the model by specifying values in a set of spatially and temporally distributed decision variables in order to test for effects on growth patterns and associated environmental degradation. The model is presently undergoing several stages of development the first of which is the construction of the data base. The development of the information system is also in progress.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

29. TITLE: Regional Modeling Abstracts - Vol. I, Vol. II, Vol. III  
 AUTHOR: Charles R. Meyers, Jr.  
 SOURCE: Regional Modeling Group, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, Attention: Candi Kelly  
 ABSTRACT: 2600 abstracts of literature acquired and indexed by the Regional Modeling Team of the Oak Ridge National Laboratory-National Science Foundation Environmental Program are given. The abstracts cover literature on the development and use of mathematical models capable of simulating the economic, societal, ecological, and land use responses of a geographical region to alternative policy decisions. Access to the abstracts can be made through various indexes: key word, author, permuted title word, and permuted key word (or phrase).

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URBANIZATION MODELS (Continued)

30. TITLE: A Multi-Regional, Multi-Industry Forecasting Model  
AUTHOR: C. C. Harris, Jr.  
SOURCE: University of Maryland  
ABSTRACT: A dynamic multi-regional, multi-industry model is presented that can be used for forecasting purposes. The emphasis is on empirical procedures. The objective of the model is to forecast industry activity on the regional level along with other regional variables, including population, income, labor force and unemployment. It is assumed that there is a tendency for labor and capital to migrate in order to maximize their returns. The migration of capital is explained with a set of industry location equations that predict the change in output by region. The migration of labor is explained by a set of population migration equations. After the industry location and population migration equations are presented, the operation of the overall model is explained.
31. TITLE: A Model for the Areal Pattern of Retail and Service Establishments within an Urban Area  
AUTHOR: M. F. Dacey  
SOURCE: Technical Report No. 2 of ONR Task No. 389-43 Contract No. 1228(37), Office of Naval Research, Geography Branch  
ABSTRACT: Three components of the areal pattern of retail, service and other commercial establishments within an urban area are (1) a dominant element formed by the location of the central business district and other commercial centers of varying sizes, (2) a local element formed by the locations of establishments within each commercial center, and (3) a diffused element formed by the scattered locations of large numbers of isolated establishments. The purpose of this study is to incorporate these components of pattern into a stochastic model for the locations of commercial establishments within an urban area. The internal structure of an urban area is described by measures of spacing between establishments having particular kinds of neighborhood relations. Though the basic model uses general functions to specify the locations of establishments, the study of specific spacing measures is primarily for an urban area where the locations are given by bivariate normal distributions. For the "normally distributed" urban area, probability distributions of distance between pairs of establishments having specified kinds of neighborhood relations are obtained. Probability distributions are also given for distance between establishments where parameters of the bivariate normal distribution are random variables obeying the gamma or beta probability law.



# URBANIZATION MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

32. TITLE: Models in Urban Planning: A Synoptic Review of Recent Literature

AUTHOR: A. G. Wilson

SOURCE: Urban Studies, Vol. 5, No. 3, Nov. 1968, pg. 249

ABSTRACT: This paper attempts to set up a rudimentary conceptual framework for planning, within which the use of models can be studied. This framework is set up in the first section of the paper, and is based on the use of an hierarchial relevance tree.

The second section of the paper delineates urban systems which can be usefully modeled, gives a set of rules for model design, and discusses some technique problems associated with model construction.

It is argued that models are developed at lower levels in such a hierarchy to represent understanding of the systems being planned. The recent literature on the development of such models is reviewed. This covers model development for spatially aggregated population and economic systems, urban structure, transport, and more briefly, social systems.

Finally, the possible applications of models is in the design process and the higher levels of the planning process, is discussed.

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33. TITLE: A Decision-Oriented Model of Urban Growth

AUTHOR: D. R. Seidman

SOURCE: Part of Proceedings of the Fourth International Conference on Operational Research Wiley-Interscience, New York, New York

ABSTRACT: The activities allocation model consists of six major submodels, each of which determines either the location of a given type of activity or the amount of land it uses. The model begins with the state of the region in 1960, defined by a series of variables measured for that year, and proceeds in a series of five-year recursive steps to 1985. Detailed descriptions of the function and structure of each of the six submodels and the dependent and independent variables used in each are presented. Most of the models consist of a nonlinear equation in which the parameters are determined by a least-squares technique in which 1950 and 1960 data are used for this calibration

# URBANIZATION MODELS (Continued)

phase. A given model may have several dependent variables, in which case the parameters are independently derived for each of the dependent variables.

34. TITLE: Choices (S.D.S.E.) in a Large-Scale Modeling Effort: The Pittsburgh Simulation Model
- AUTHOR: N. Douglas, Jr. and W. A. Steger
- SOURCE: Part of Urban Information and Policy decisions, 2nd Annual Conference on Urban Planning Information Systems and Programs
- ABSTRACT: The elements of the Pittsburgh urban renewal simulation model are described, the current problems in formulation and refinements are discussed and the choices made in developing the models are investigated.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

35. TITLE: Seven Models of Urban Development - A Structural Comparison
- AUTHOR: I. S. Lowry
- SOURCE: Rand Corporation, Santa Monica, California
- ABSTRACT: The significance of the variables included in model building and the coherence of the models formal structure are emphasized. An adequate system of interdependence is spelled out by the theory of the market for urban land, the formal structure of which is elaborate but easily grasped. In choosing a model for a particular purpose consideration must be taken of both omissions and inclusions. A theory of the urban land market is presented in paradigm which provides a number of important variables and relationships among variables. Seven specific models are reviewed in detail. Each was chosen to illustrate a particular strategy of simplification. The formal structure of the models, the conceptual definitions of specific variables in particular, is carefully considered.
- The models discussed, and their major focus, are as follows: (1) land use: The Chicago Area Transportation Study (CATS) Model (2) Land Use Succession: The University of North Carolina Model (3) Location: Empiric Model (4) Migration: Polimetric Model (5) Hybrid: Pittsburgh Model (6) Market Demand: Penn-Jersey Model (7) Market Supply: San Francisco Model.

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URBANIZATION MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

36. TITLE: Models and Techniques for Urban Planning  
 AUTHOR: Douglas B. Lee  
 SOURCE: National Technical Information Service,  
 Report No. AD 843-620  
 Springfield, Virginia 22151  
 ABSTRACT: The intent of the report was to provide an information base for primarily technically skilled people who might be interested in applying quantitative methodology to the modeling of urban phenomena. Thus we have tried to indicate how techniques might be applied, and also how they have been applied in the past to urban problems. Land use models were selected as the main area of interest, but the topic is extremely open-ended, and difficult to define, with the result that the report lacks a certain kind of elegance.  
 Chapters 1-5 proceed from the general to the specific. Chapter 2 describes a number of abstract attributes of models which provide a framework for further discussion. Chapter 3 sketches out a variety of concepts and techniques that seem to be relevant to urban models, and attempts to relate these concepts to modeling of social activities. Chapter 4 is an overview of the modeling process, emphasizing those aspects that are critical to urban modeling. These three chapters abstract as much as possible of what can be said about urban modeling, with the 5th chapter being a description of the specifics of several applications. Finally, Chapter 6 gives a summary and suggested further work.

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37. TITLE: Simulation Models in Urban and Regional Planning  
 AUTHOR: K. J. Schlager  
 SOURCE: Part of Urban Information and Policy Decisions, 2nd Annual Conference on Urban Planning Information Systems and Programs  
 ABSTRACT: Some recent experience with computer simulation models in regional planning by the Southeastern Wisconsin Regional Planning Commission are described. The models are explained in the context of comprehensive planning as follows: the function of two typical simulation models as part of a regional land-use-transportation planning process is delineated: the contrasting roles of forecasting models, design models and plan implementation

URBANIZATION MODELS (Continued)

control models are clarified: the complementary aspects of mathematical optimization models and their function relative to simulation models are described: and two computer simulation models, one relating to a regional land development, are explained.

38. TITLE: A Simulation Model of the Residential Space Market in San Francisco: A New Tool for Urban Renewal Planning and Programming
- AUTHOR: I. M. Robinson
- SOURCE: Part of Urban Information and Policy Decisions, 2nd Annual Conference on Urban Planning Information Systems and Programs
- ABSTRACT: The nature and operations are described of a mathematical simulation model which was developed by the staff of Arthur D. Little, Inc., to assist in preparing a Community Renewal Program for the city and county of San Francisco.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

39. TITLE: Measuring the Impact of a New Urban Highway on Community Traffic
- AUTHOR: J. J. Demetsky (University of Virginia) and F. D. Shepard (Virginia Highway Research Council)
- SOURCE: Traffic Engineering, July 1972, V42, n10, p 42 (4) technical report
- ABSTRACT: Five primary methods for predicting the impact of a new highway on local or community traffic are described: (1) inferences from the modeling system of the transportation planning process; (2) micro-assignment models; (3) subjective evaluations; (4) direct measurements of local traffic volumes; and (5) direct measurements of local traffic adjustments. The conventional transportation planning methodology is shown to provide inadequate measures of traffic volumes at the detailed level required to study local traffic. A forecasting model system for transportation planning is diagrammed (2 photos, 1 diagram).

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URBANIZATION MODELS (Continued)

40. TITLE: A Growth Allocation Model for the Boston Region  
 AUTHOR: D. M. Hill  
 SOURCE: Journal of the American Institute of Planners, 31(2)  
 ABSTRACT: The model is based on extremely simple concepts and represents the first case of a complete model covering all aspects of urban location. The future growth of each of a number of activities in a number of subareas of the Boston Metropolitan Region is projected in short steps, with each step depending upon the results of previous steps. In concept the development of each activity in each subarea influences future development by way of competition for land and changed accessibilities. The initial analysis used in establishing the parameters for the model is based on multiple correlation, and shows extremely close correspondence between the estimates generated by the model and actual historical events. When the model is used as a projection device, it is particularly interesting to note that current trends do not continue, but are changed by later events. The decline of the center city is checked, as is the rate of growth of the inner suburban ring. This model is particularly flexible in that it can accommodate the influences of a very large number of variables. It may be contrasted with the Pittsburgh model in that it contains very little explicit analysis of locational behavior and depends primarily on a blanket interpretation of past events.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

41. TITLE: A Multi-Phasic Component Study to Predict Storm Water Pollution from Urban Areas  
 AUTHOR: J. G. Cleveland, et al, Avco Economic Systems Corporation, Washington, D. C.  
 SOURCE: NTIS PB-197 169, Dec. 1970 (254 research report)  
 ABSTRACT: Ten mathematical models are presented for predicting storm water pollution from land activity, precipitation, and runoff in an urban area and are evaluated in application to several selected demonstration cities. Criteria for pollution control strategies are also presented, with various structural and nonstructural control measures, their general effectiveness, and costs. The study concludes that: (1) storm water pollution prediction models are feasible but of limited application unless adequate data are available on hydrological, precipitation, and runoff characteristics, as well as land activity detail for representative metropolitan areas; and (2) storm water pollution control for most effectiveness should relate to the specific characteristics of an urban area.

URBANIZATION MODELS (Continued)

Maximum economies will derive from pollution abatement measures taken during the early stages of area development.

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42. TITLE: Mathematical Models for Decision-Making in Population and Family Planning  
AUTHOR: H. Correa, University of Pittsburgh, and J. D. Beasley, Tulane University  
SOURCE: American Journal of Public Health, Jan. 1971. v61, n1, p 138(12) technical report  
ABSTRACT: Methods of mathematical programming - linear and quadratic - are applied to the problem of optimal techniques for population and family planning. A progression of equations are presented on the assumption that such planning will utilize the cheapest direct contraceptive controls per pregnancy avoided. Because results obtained from mathematical models could create attitudinal conflicts with populations that would benefit most, the results should be reviewed as only one of the criteria considered in planning programs.
43. TITLE: Industrial Location Model  
AUTHOR: S. H. Putman  
SOURCE: Technical Bulletin No. 5, Dec. 1963, Department of City Planning, Pittsburgh, Pennsylvania
44. TITLE: Transportation Planning Models  
AUTHOR: M. M. Webber  
SOURCE: Traffic Quarterly, Vol. 15, No. 3 (July 1961) pg 373-390

## APPENDIX E

### SURFACE WATER MODELS

1. **TITLE:** DOSAG-1 Stream Quality Model
- AUTHOR:** Texas Water Development Board (TWDB)
- SOURCE:** Systems Engineering Division, TWDB, Austin, Texas
- OBJECTIVE/  
PURPOSE:** Initial screening of alternatives, i.e.; waste loadings and discharge locations and the selection of those warranting more detailed analysis.
- ASSUMPTIONS:** Steady State Hydraulics
- STATUS:** Operational computer program. Selected by EPA as basis for river basin studies, i.e.; Schuylkill River Basin Model and Chattahoochee-Flint River Basin Mathematical Model
- OUTPUT:** Calculates mean monthly values of the biological oxygen demand (BOD) and the dissolved oxygen (DO) concentrations at various locations in a stream system. Also, can compute flow augmentation.
- INPUT:** Geometric-Hydraulic
- Number of tributaries to the river basic mainstem and length of each
  - Length of the river reaches between points of tributary inflow
  - Velocity-discharge and depth-discharge relationships for each tributary and for the mainstem
- Waste Discharge
- Location, mean flow, and total biochemical oxygen demand of waste loads to the system
  - Location and mean flow of withdrawals (if any) from the system
- Chemical-Biochemical
- Mean total biochemical oxygen demand and dissolved oxygen concentration at the upstream end of each head-water reach in the system, and for the incremental runoff in each reach.

SURFACE WATER MODELS (Continued)

2. TITLE: POND Computer Model
- AUTHOR: University of Texas Marine Sciences Institute
- SOURCE: W. B. Brogden, University of Texas Marine Sciences Institute, Port Aransas, Texas
- OBJECTIVE/  
PURPOSE: This model was designed for both teaching and research in the environmental chemistry and biology
- ASSUMPTIONS: Theoretical relationships between 18 chemical, physical, and biological variables. Single well-mixed reservoir.
- STATUS: Operational computer program. Runs on the U. T. CDC6400 system with Teletype terminal graphics (TSP plotter).
- OUTPUT: Computes hourly changes in 14 variables, printer or plotter output can be selected. Variables are as follows: Oxygen, CO<sub>2</sub>, pH, Bicarbonate, Carbonate, Dissolved organic matter, "soft" and "hard," Particulate organic matter, Phosphate, Ammonia, Nitrate, Phytoplankton, Zooplankton, and Inorganic particulate matter.
- INPUT: Initial conditions for the above variables plus: salinity, temperature, wind speed, water depth, and light intensity versus time curve. Input uses relatively free field techniques and English language-like instructions.
- COMMENTS: This model uses subroutines which could be adapted to modeling segmented estuaries or lakes; in this application however, only one compartment is represented, with no inflow or outflow.
3. TITLE: HEC-3 Reservoir System Analysis
- AUTHOR: Hydrologic Engineering Center
- SOURCE: Hydrologic Engineering Methods for Water Resources Development, Vol. 1, Computer Program 723-X6-22030, U.S. Army Corps of Engineers, Davis, California
- ABSTRACT: This program written in FORTRAN IV performs a multi-purpose routing of a reservoir system by any number of periods of uniform or varying length per year based on varying flow requirements at reservoirs, diversions and downstream control points and power peaking and energy requirements at reservoirs. It can accept any configuration of reservoirs, diversions, power plants and control points, and will accept system power demands that override individual power plant requirements, but does not provide for channel routings or percolation losses. It can assign economic values to all outputs and summarize and allocate these in various ways. It can automatically iterate to optimize yield at a specified location. Great flexibility of input and output requirements and of



## SURFACE WATER MODELS (Continued)

computation technique enable the program to solve relatively simple problems with minimum effort or elaborate complex problems with a high degree of accuracy.

All requirements are supplied from reservoirs so as to maintain a specified balance of storage in all reservoirs, insofar as possible. At reservoir stages below specified levels, releases from storage at each reservoir are reduced to a secondary specified flow at each control point until all active storage is withdrawn. Provision is included for shortage declaration which will reduce desired flows and diversions covering a period less than one year. The shortage declaration is based on total storage at the beginning of a specified period at specified reservoirs. The declared shortage is proportional to the total storage deficiency in these reservoirs at the beginning of that period.

Provision is included for changes of basin development or operation plan or demand schedules at the ends of any designated years.

The program is capable of performing short-interval flood studies, accounting for travel time between control points but not for channel storage effects. It will provide maximum releases subject to downstream controls whenever there is water in flood control space at a reservoir and will store above full reservoir level to the extent that surcharge storage is possible and permitted. Provision is included for contingency allowances both for flood control and water supply as a function of local inflow above each control point downstream of reservoirs, diversions out of the stream and into the stream (including return flows) must be specified as fixed amounts for each period, except that return flows for any period can be a ratio of any previously computed diversion for that period.

4. TITLE: QUAL-1, Stream Quality Routing Model
- AUTHOR: Texas Water Development Board
- SOURCE: Systems Engineering Division, Texas Water Development Board, P. O. Box 13087, Capitol Station, Austin, Texas 78711
- ABSTRACT: QUAL-1 was developed to simulate the spatial and temporal variations of several specific water quality parameters in streams and canals. These parameters are:
1. Temperature
  2. Biochemical Oxygen Demand/Dissolved Oxygen
  3. Conservative Minerals
- QUAL-1 routes these parameters through a system of streams and canals on an hourly basis. It assumes that the major

## SURFACE WATER MODELS (Continued)

transport mechanisms, advection and dispersion, are significant only along the main direction of flow (longitudinal axis of the stream or canal). It allows for multiple waste discharges, withdrawals, tributary flows and incremental runoff. It also has the capability to compute required dilution flows for flow augmentation to meet any prespecified dissolved oxygen level.

QUAL-1 is currently operational on the RCA Spectra 70/45, the CDC 6400 and 6600, and the UNIVAC 1108 computers; thus the program is essentially machine independent. The computation time depends on the size of the stream system being analyzed and the number of parameters that are routed. The run time on the RCA Spectra 70/45 for a stream system of 120 river miles through which only BOD/DO is routed is approximately 15 minutes. The run time on the CDC 6400 and the UNIVAC 1108 computers is about 20 times faster than on the RCA Spectra 70/45.

5. TITLE: RESOP-1, Detailed Reservoir Operation Program
- AUTHOR: Texas Water Development Board
- SOURCE: Systems Engineering Division, Texas Water Development Board, P. O. Box 13087, Capitol Station, Austin, Texas 78711
- ABSTRACT: RESOP-1 is designed to meet the need of the Texas Water Development Board for performing detailed analyses of the annual yield of individual reservoir sites. Although RESOP-1 has the capability to analyze only one reservoir at a time, it can be used iteratively on a set of reservoirs connected by gravity river reaches. The iterative use results in the determination of the firm annual yield of the entire river basin assuming no pump-back capability. The program operates on a monthly time-increment and is currently structured to simulate up to a 25-year period of deterministic input data. The deterministic data required is (1) monthly unregulated inflow, (2) monthly spills into the reservoir (if any), (3) monthly net lake surface evaporation data. The input data required is supplied both by magnetic tape and cards. The input and output data formats are structured to be compatible with existing card formats contained in the Board's file and to provide an output listing which is similar to that of the previous reservoir operation program.
- OBJECTIVES: The program has three objectives:
- Simulate the operation of a reservoir over a given period.
  - Determine the firm yield of a reservoir site.
  - Provide a conservative mineral reservoir quality routing.

## SURFACE WATER MODELS (Continued)

Corresponding to the objectives, the user may select from three options within the program:

- Option A --- Forward Operation
- Option B --- Reverse Operation
- Option C --- Forward Operation with Quality Routing.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

6. TITLE: A Summary of Capabilities for Analysis of Water Resource Planning Problems
- AUTHOR: Texas Water Development Board (TWDB)
- SOURCE: Systems Engineering Division, Texas Water Development Board, Austin, Texas 78711
- ABSTRACT: The brochure acquaints potential users with the computer-oriented planning capabilities that the TWDB now has available. It contains brief descriptions of the capabilities and the various system simulation and optimization computer programs that support them. It includes data requirements and example results. These capabilities are (1) reservoir operations analysis (2) river basin analysis (3) multibasin simulation and optimization (4) multibasin water quality analysis (5) irrigation demand simulation (6) ground water basin simulation (7) stream quality simulation (8) stratified reservoir simulation (9) estuary hydrodynamics simulation (10) estuary salinity simulation.

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7. TITLE: The Kentucky Watershed Model and OPSET
- AUTHOR: L. D. James
- SOURCE: University of Kentucky Water Resources Institute
- ABSTRACT: The Kentucky Watershed Model is basically a translation of the Stanford Watershed Model [E-5] into FORTRAN computer language. It is a very complex continuous synthesis, two phase watershed model, implying that the land phase and the channel phase are each modeled as separate entities. The program is fairly large, requiring over 70500<sub>8</sub> storage locations, and requires substantial computer time to operate. The input data requirements are quite lengthy but the bulk of it is easily accessible from published climatological data. Using this data, the most significant of which is rainfall, the program produces synthesized stream flow hydrographs and moisture storage values based on specified parameters which define the relationships

## SURFACE WATER MODELS (Continued)

representing the various processes involved in the hydrologic cycle. OPSET is a companion program which uses optimization techniques to determine the values of 13 of the input parameters to the Kentucky Model such that the best approximation to observed results are produced. It uses a streamline version of the Kentucky Model as a central core and by testing various values of the parameters, attempts to find the combination which gives the "best fit" with observed data. It is also a fairly large program, consisting of over 2400 source statements and requiring 100500 storage locations on the CDC 6600, and well over 100 seconds of central processing time to execute.

8. TITLE: Numerical Simulation of Watershed Hydrology, Aug. 1970, (University of Texas Model)
- AUTHOR: B. J. Claborn and W. L. Moore
- SOURCE: Civil Engineering Department, University of Texas, Austin, Texas
- ABSTRACT: This report includes a discussion of (1) the Runoff Phenomenon, (2) methods of estimating storm runoff, and (3) the Stanford Watershed Model IV, plus a listing, evaluation and discussion of a new mathematical model of the runoff process. As noted in the author's abstract, "The Stanford Model has been revised and used as a pattern for developing a new watershed simulation model."
- The University of Texas Model is written in Fortran IV and has about 1,000 source statements.
9. TITLE: USDAHL-70 Model
- AUTHOR: H. M. Holtan and N. C. Lopez
- SOURCE: U. S. Department of Agriculture, Hydrograph Laboratory Technical Bulletin No. 1435
- ABSTRACT: This program was written in Level E Fortran for use on an IBM 360-30 computer. The model, in the words of the authors, is "the beginning of an effort to express watershed hydrology as a continuum." Its primary objective is to serve the needs of watershed engineering by providing detailed information on the runoff process to assist in the design of engineering structures. It is based on a series of empirical relationships.
- Input consists of a continuous record of rainfall (average over the watershed). Snowfall is tabulated as water equivalent for the watersheds modeled. An example is given where the watersheds ranged in size from 3 to 98 square miles.

## SURFACE WATER MODELS (Continued)

Application of the model to four watersheds (Ohio, Texas, Nebraska, Florida) indicated good correlation between monthly observed and computed runoff. Continuous synthesis of mean daily flows at Upper Taylor Creek, Florida showed good agreement over a five-year period. Standard output includes a daily printout and a monthly summary at the end of each year. The daily data includes day of year, inches of rainfall, inches of runoff, mean daily cfs, precipitation excess, etc.

10. TITLE: HEC-2, Water Surface Profiles  
 AUTHOR: Bill S. Eichert  
 SOURCE: Hydrologic Engineering Center, Corps of Engineers, Sacramento, California  
 ABSTRACT: The HEC-2 water surface profile program computes flow profiles for river channels of any cross section for either supercritical or subcritical flow conditions. Special consideration is given to bridges, culverts, weirs, embankments, and dams. The program allows variable roughness, islands, bends, levee overflow, river confluences, and waterfalls. Channel roughness can be established from known high water marks if desired.
- The program, originally written for a CDC 6600, requires approximately 147000<sub>g</sub> locations on that machine. Most of the core storage is used only to retain the results of a series of flow profiles (up to 15) which are summarized for comparison at the end of all computations. If this option is not required, core storage can easily be reduced to about 40000<sub>g</sub> locations on the CDC 6600.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

11. TITLE: Computer Programs in Hydrology  
 AUTHOR: C. E. Bowers, A. F. Pabst, S. P. Larson  
 SOURCE: National Technical Information Service, Springfield, Virginia 22151, Report No. PB 208-692  
 ABSTRACT: A study was undertaken to review available programs in hydrology and to provide information on representative programs. Information ranging from the title only of the program to listings, source decks, and documentation was reviewed for about 200 programs. Of these, 25 were selected for operation on a CDC computer and/or preparation of an abstract. The report discusses problems associated with adapting programs to a given computer and with understanding the technical procedure on which the program was based.

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SURFACE WATER MODELS (Continued)

12. TITLE: A Computer Model for Some Branching-Type Phenomena in Hydrology
- AUTHOR: K. H. Liao and A. E. Scheidegger
- SOURCE: Bulletin of International Association of Scientific Hydrology, 13(1), 5-13
- ABSTRACT: In hydrology, branching-type phenomena occur in several instances, for example in ground-water flow (splitting flow channels in a porous medium) and in the formation of a natural river network (combining, i.e., inverse branching, of small rivers to form large rivers). Such phenomena can be treated by the statistics of topological bifurcating arborescences. Ensembles of arborescences can be generated on a computer and expectation values for observables can be calculated. In this fashion, the laws of dispersion processes in flow through porous media and Horton's law of stream numbers in drainage basins are the outcome of very simple statistical assumptions.
13. TITLE: Simulating the Behavior of a Multi-Unit, Multi-Purpose Water-Resource System
- AUTHOR: M. M. Hufschmidt
- SOURCE: Part of: Symposium on Simulation Models, Methodology and Application to the Behavioral Sciences, Southwestern Publishing Co., Cincinnati, Ohio
- ABSTRACT: The optimal design of a multi-unit, multi-purpose water-resource system was investigated through the development of a model river basin system consisting of four reservoirs, two hydropower plants, an irrigation distribution system, and a flood damage center. The behavior of this system for different designs was simulated on an IBM 704 computer. The results of these simulation studies are presented and certain tentative conclusions are set forth.
14. TITLE: A Mathematical Model for Simulating the Hydrologic Response of a Watershed
- AUTHOR: L. F. Huggins and E. J. Monke
- SOURCE: Water Resources Research, 4(3) 529-539
- ABSTRACT: A general mathematical model was developed to simulate the surface runoff from watersheds. Based upon the integration of the concepts of physical hydrology into quantitative relationships, the model avoids the use of lumped parameters by delineating the watershed as a grid of small, independent elements. Because of the resultant freedom from fundamental assumptions regarding the form of the system equations and from the permissible

# SURFACE WATER MODELS (Continued)

small areal resolution of the model, very complex combinations of watershed and storm conditions may be studied. Application of the model to two very small watersheds indicated a need for additional research to define better the relationships for surface runoff and infiltration to improve the reliability of the simulated runoff hydrographs.

\* \* \* \* \* NON- MODEL \* \* \* \* \*

15. TITLE: Systems Analysis for Water Quality Management - Survey and Abstracts, Sept. 1971  
AUTHOR: Enviro Control, Inc., 1250 Conn. Ave., N. W. Washington, D.C., 20036  
SOURCE: Report No. SD 1 09/71, Office of Water Programs, U. S. Environmental Protection Agency, Washington, D. C.  
ABSTRACT: A survey of the current state-of-the-art in systems analysis for water quality management has been conducted. The survey is divided into two parts. Part I gives an introductory guide to the relevant analytical considerations and techniques together with assessments of the capabilities and limitations of available systems analysis approaches. Part II gives relatively detailed abstracts of a representative sampling of papers in relevant analytical input areas and in the major water quality modeling areas. The abstracts give both technical content of the papers and critical assessments.

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16. TITLE: General Hydrologic System Model  
AUTHOR: V. T. Chow and V. C. Kulandaiswamy  
SOURCE: Journal of the Hydraulics Division, 96(HY6), 791-804  
ABSTRACT: From the analysis of hydrologic data of a number of watersheds, the proposed hydrologic system model is found to produce very satisfactory results. It even produces different instantaneous unit hydrographs for different hydrologic inputs of the same watershed, thereby relaxing the conventional constraint that only one unique instantaneous unit hydrograph or unit hydrograph exists for a given watershed. The model also reproduces the complete loop structure of the storage and direct runoff relationship. This is a feat which cannot be accomplished by most conventional hydrologic models. For detailed analysis and hydrologic design of hydraulic structures and water resources systems, the proposed hydrologic system model is a very useful tool. The model recommended for practical

# SURFACE WATER MODELS (Continued)

application is quasi-linear but can be treated as entirely nonlinear.

17. TITLE: Least Squares Estimation of Constants in a Linear Regression Model  
AUTHOR: L. D. James and W. O. Thompson  
SOURCE: Water Resources Research, 6(4), 1062-1069  
ABSTRACT: Least squares can be used for estimating constants in a linear recession model from published average daily streamflows. A model with two recession constants was derived and successfully tested on a number of Kentucky streams. It can be used to estimate recession constants from daily streamflows stored on magnetic tape or punched cards without resorting to time-consuming graphical techniques. Equations and procedures are provided for recessions represented by either one or two recession constants using both a weighted and unweighted estimation procedure. In applying the two techniques, empirical evidence indicates the simpler unweighted procedure is preferable.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

18. TITLE: A Partial Annotated Bibliography of Mathematical Models in Ecology  
AUTHOR: J. A. Kadlec, Principal Investigator  
SOURCE: Analysis of Ecosystems Program, International Biological Program, University of Michigan, School of Natural Resources, Ann Arbor, Michigan  
ABSTRACT: The report contains 621 abstracts of literature examined by the Analysis of Ecosystems Program Group during the summer of 1970 and supported by a National Science Foundation grant. The abstracts cover literature in the fields of biology, hydrology, soils, meteorology, and ecology.

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SURFACE WATER MODELS (Continued)

19. TITLE: Computer-oriented Method of Optimizing Hydrologic Model Parameters
- AUTHOR: D. G. DeCoursey and W. M. Snyder
- SOURCE: Journal of Hydrology, 9, 34-56
- ABSTRACT: Much hydrologic information and significant advancement in hydrologic understanding are based upon interpretive analysis of hydrologic observations. The rational beginning point of such an inductive process is the construction of a conceptual model. Realistic hydrologic models are not normally simple forms. The quantification and verification of realistic hydrologic concepts requires specialized optimizing methods. Optimum values of the coefficients of mathematical models can be found by reduction of the residual error associated with estimates of the coefficient values. Orthogonal corrections to the coefficients are insured by using principal component analysis to regress the error term on a group of correction terms. A digital computer program capable of performing the optimization has been tested on four models of varying complexity and used on several fieldscale models. The optimized values of the coefficients are a function of the number of roots used in the solution. Convergence is not a function of the number of observations, feedback, random noise, or equation complexity. While the optimization method discussed here was developed primarily in response to specialized needs in hydrologic modeling it should be applicable in any disciplines with significant inputs of interpretive data analysis.
20. TITLE: Mathematical Model for Water Distributing Systems
- AUTHOR: Mehdi S. Zargamee, Associate Professor of Math, Mehr University of Technology, Tehian, Iran
- SOURCE: Journal of Hydraulics Division (ASCE), Jan 1971, v97, nHY1, pl(13) technical feature
- ABSTRACT: A mathematical model is developed for predicting the steady-state flow pattern for a water distribution system consisting of conduits, pumps, pressure-reducing valves, and reservoirs. The model is a computerized numerical simulation of the network. Because each component of the network is governed by a nonlinear flow formula, the equilibrium of flow in the network is governed by a system of non-linear equations. The solution of this system is sought by the Newton iteration method. The model is verified against the Harty Cross method and applied to the determination of the flow pattern of an actual water network. (Diagrams)

SURFACE WATER MODELS (Continued)

21. TITLE: Parametric Study of Power Plant Thermal Pollution  
AUTHOR: A. Nahavandi and J. Campisi, Newark College of Engineering  
SOURCE: WPCF Journal, Mar. 1971, v43, n3, p506 (8 1/2) research report  
ABSTRACT: The power capability and thermal pollution effect of steam power plants located on rivers or streams were analyzed to determine the power capability for a given downstream temperature. Equations for condenser cooling water were derived. By means of a digital computer program, computer generated charts show that power capability and thermal pollution (ratio of downstream temperature to condenser temperature, both referred to atmospheric) are direct and inverse linear functions, respectively, of upstream temperature (ratio of upstream and condenser discharge temperatures, both referred to atmospheric). Increase in recirculation adversely affects power capability and decreases thermal pollution (4 charts, 1 diagram).
22. TITLE: Modeling and Control of the Pollution of Water Resources Systems via Multilevel Approach  
AUTHOR: Yacov Y. Haimes, Case Western Reserve University  
SOURCE: Water Resources Bulletin, Feb. 1971, v7, n1, p93 (7 1/2) research report  
ABSTRACT: A mathematical model for controlling water pollution situation in which effluent is discharged directly into river, lake or bypass pipe leading to a treatment plant is given. The model divides the plant into subsystems and the pollution effluent input vector to each subsystem includes the water quantity and characteristics BOD, DO, pH, conductivity, temperature, algae-, phosphate-, nitrate-content. Treatment cost and quality transition functions, and system model constraints are included. (2 diagrams)
23. TITLE: An Experiment in Deterministic Watershed Modeling  
AUTHOR: Carrel E. Dunn, Montana State University  
SOURCE: Water Resources Bulletin, Apr. 1971, v7, n2, p343 (5) research report.  
ABSTRACT: Report on the construction of an experimental watershed model in the form of a Fortran-IV computer program which would relate weather input to hydrologic output, and would not require calibration using historical watershed data, illuminates the difficulties involved in such a project. The watershed volume was divided into layers of cells representing the overland flow, the vadose and the phreatic zones, but this was found to be an oversimplification.

SURFACE WATER MODELS (Continued)

Although this primitive model has many deficiencies, the general approach of a deterministic model which does not require calibration seems plausible. (1 diagram)

24. TITLE: Component Testing within a Comprehensive Watershed Model  
AUTHOR: C. B. England and M. J. Coates, both: USDA  
SOURCE: Water Resources Bulletin, Jun 1971, v25, n5, p421 (6) technical feature  
ABSTRACT: Mathematical watershed model containing a complete soil moisture accounting system simulates the hydrologic processes measured in a weighing lysimeter at Coshoeton, Ohio. Data from a four-year rotation are used to calibrate the parameters initially selected for the model, and data from the succeeding four years are used to evaluate the predictions. Reasonable agreement is obtained between observed and predicted percolation and evapotranspiration values. (9 charts)
25. TITLE: Mathematical Models for the Prediction of Temperature Distributions Resulting from the Discharge of Heated Water into Large Bodies of Water  
AUTHOR: R.C.Y. Koh and Lon-Nien Fan, Tetra Tech, Inc.  
SOURCE: Water Quality Office, EPA Report; Water Pollution Control Research Series; Program No. 16130 DWO, USGPO, Oct 1970 (219) technical report  
ABSTRACT: The rise in the production of electric power has resulted in attendant generation of large quantities of waste heat. In order to properly manage the great volume of waste heat that will be produced in the future, it is essential that a body of knowledge be developed on the transport behavior and effects of heat on the total environment. One important item in this necessary body of knowledge is the ability to develop methods of accurately forecasting the effects of waste heat discharge into a large body of water. In the overall of excess temperature prediction, the following considerations should be stressed: momentum of the discharge, buoyancy of the discharge, dispersion due to ambient turbulence, ambient density stratification, ambient current structure, solid boundaries, and surface heat exchange. Although mathematical models for the study of dispersion of sewage effluent, the effect of thermal dispersion on the surface, and other related fields already exist, no general method has been formulated to predict the temperature distribution resulting from waste heat discharge. The general mixing and dispersion phenomena which accompany the discharge of heated cooling water into a large body of water are complex and difficult

## SURFACE WATER MODELS (Continued)

to analyze. An investigation is, therefore, undertaken to determine the interrelationships of the various mechanisms which contribute to irregularities within the flow field. Studies are made of the initial and intermediate phases of mixing in the event the discharge is made at depth, at the surface, or in the case when it is influenced by passive turbulent diffusion from a continuous source in a uni-directional current. Finally, mathematical models are projected for different prevailing conditions: initial mixing for subsurface discharge, intermediate phase for subsurface discharge, surface horizontal buoyant jet passive diffusion in a current. (34 charts, 17 diagrams)

26. TITLE: Water Quality Simulation Model  
AUTHOR: G. R. Grantham, et al, Camp, Dresser, and McKee Consulting Engineers  
SOURCE: Journal of the Sanitary Engineering Division (ASCE), Oct 1971, v97, nSA5, p 569 (16) research report  
ABSTRACT: A model for simulating stream hydrology and water quality is developed as part of a project to study the economic benefits of low-flow augmentation versus increased degree of wastewater treatment. The model simulates surface water hydrology and the dissolved oxygen balance in streams; simulation is used as a replacement for experimenting with the real system because it is more convenient, less time consuming, and less costly. Input data from the Farmington River Basin in Connecticut were used for testing the model; this application successfully generated stream-flow and water quality data which compared reasonably well with recorded data.
27. TITLE: Delaware River Basin Modeling  
AUTHOR: L. G. Hulman and D. K. Erickson, U.S. Army Engineering District, Philadelphia  
SOURCE: Journal of the Hydraulics Division (ASCE) Jan 1972, v98, nHY1, p105 (16) research report  
ABSTRACT: The record northeastern U. S. drought of the 1960's has necessitated a detailed reappraisal of water resource systems previously proposed in the effected areas to determine the extent of changes in available yield. The ability to judge the competence of proposed engineering structures in the Delaware Basin to meet flow requirements has been hampered by the diversity of projects, the political constraints on existing projects in the upper portion of the basin, and numerous alternative demands on available surface water. To facilitate analysis of the effects of

SURFACE WATER MODELS (Continued)

the record drought on systems yields, a mathematical modeling technique was developed to allow simulation of the lower Delaware Basin and proposed engineering structures. The technique and its application to the Delaware are analyzed. The results of the reappraisal of project yields utilizing the model are presented and compared with pre-1960 yield estimates. (2 maps, 4 charts, 1 graph; 1 diagram)

28. TITLE: Stream Quality Modeling by Quasilinearization  
AUTHOR: E. S. Lee and I. Hwang, Kansas State University  
SOURCE: Journal Water Pollution Control Fed., Feb 1971, v43, n2, p306 (11) research report  
ABSTRACT: The quasilinearization technique, generalized Newton-Raphson method, can be used to identify or estimate the parameters in river or stream pollution. By this technique, the parameters can be estimated directly from the differential equations representing the pollution model and from measured data such as biochemical oxygen demand and dissolved oxygen. Several examples illustrate the technique. (9 charts)
29. TITLE: Dispersion Model for a Stream with Several Waste Inputs and Water Intakes  
AUTHOR: L. T. Fan, et al, Kansas State University  
SOURCE: Contract # 1K4 GM35397-01, Office of Water Resources Research and Water Resources Bulletin, Dec 1971, v7, n6, p1210 (11) research report  
ABSTRACT: An analytical solution has been developed for BOD and DO profiles in streams with axial dispersion. The model may be used for optimization in water quality management and control. The dispersion model is more realistic and useful than the plug flow model because the concentration profiles are not discontinuous. The interactions between water quality depletion in the neighborhood of a downstream discharge, and the effect of changing stream properties may be simultaneously considered. Since the model includes continuous additions and removal of BOD and DO, it is suitable for representing situations where agricultural runoff is a major pollution factor. (2 charts, 4 graphs, 2 diagrams)

SURFACE WATER MODELS (Continued)

30. TITLE: A Predictive Model for Thermal Stratification and Water Quality in Reservoirs
- AUTHOR: M. Markofsky and D.R.F. Harleman, Both Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Dept. of Civil Engineering, MIT
- SOURCE: EPA Report; Water Pollution Control Research Series; Program #16130DJH; USGPO, Jan 1971 (283) technical report
- ABSTRACT: The development of a one-dimensional water quality mathematical model incorporates the internal flow pattern predicted for a stratified reservoir from the temperature model of Huber and Harleman. The water quality parameters of rivers and streams entering the reservoir are assumed to be known. The entering water, after initial mixing, seeks its own density level within the horizontal stratification field. The outflow of water through the reservoir outlet is assumed to originate from a withdrawal layer whose vertical thickness is a function of the time-dependent vertical temperature-density gradient. The model predicts concentration of particular water quality parameters in outflow water as a function of time, and with non-conservative pollutants, incorporates generation and/or decay rates. A test by comparing measurements of outlet concentrations from pulse injections of a conservative tracer in a laboratory reservoir with the model demonstrates agreement between the two. A practical application was made by solving the coupled set of water quality equations for BOD and DO predictions for Fontana Reservoir. Direct comparisons of the water quality model predictions with field measurements of dissolved oxygen are limited by the lack of input data. A sensitivity analysis to various assumptions on the input data illustrates the mechanics of the model. The report concludes the model is capable of predicting the effect of reservoir impoundments on water quality. (1 map, 75 charts, 4 diagrams, 3 photos)
31. TITLE: Physical Processes in the Spread of Oil on a Water Surface
- AUTHOR: J. A. Fay, MIT
- SOURCE: Contract # DOT-CG-01-381-A, USCG, presented at API/EPA Conference on Prevention and Control of Oil Spills, Jun 15-17, 1971, Washington, D.C., p463 (5) research report
- ABSTRACT: Formulae are presented for calculating the extent of oil slick spread on water as a function of time. Included in the calculations are one-dimensional and two-dimensional (axi-symmetric) slick.

SURFACE WATER MODELS (Continued)

32. TITLE: Mathematical Model of River Hooghly  
AUTHOR: D. M. McDowell (Manchester Univ.) and D. Prandle (Nat'l Research Council of Canada)  
SOURCE: Journal of the Waterways, Harbors and Coastal Engineering Div (ASCE), May 1972, v98, nWW2, p225 (18) technical report  
ABSTRACT: Finite difference solutions to one-dimensional equations of motion for shallow water waves have been applied to the tidal region of the River Hooghly in India. The mathematical model formulated is capable of satisfactory reproduction of tidal levels and velocities throughout the river section considered. (1 map, 1 chart, 9 graphs, 4 diagrams)
33. TITLE: Dynamic Modeling of Stream Quality by Invariant Imbedding  
AUTHOR: E. S. Lee and I. K. Hwang, Kansas State University  
SOURCE: Water Resources Bulletin, Feb 1971, v7, n1, p102 (13) research report  
ABSTRACT: By using estimator equations obtained by invariant imbedding, pollution parameters can be estimated directly from differential equations representing the pollution model and from measured "noisy" data such as BOD and DO. A sequential estimation scheme is obtained, so that only current data are needed to estimate current or future values of the unknown parameters, saving computer time and computer memory space. Several examples are solved to illustrate the technique. (11 charts)
34. TITLE: Optimal Water Quality Management for the Houston Ship Channel  
AUTHOR: A. J. Hays (TRACOR, Inc., Texas) and E. F. Gloyna (Univ. of Texas)  
SOURCE: Journal of the Sanitary Engineering Division (ASCE) Feb 1972, v98, n1, p195 (20) research report  
ABSTRACT: A finite-difference, steady-state mathematical model was employed to predict summer DO profiles resulting from wastewater discharges and other influences for a one-dimensional, homogeneous system (Houston Ship Channel). Two optimization models, an implicit enumeration and a nonlinear programming algorithm, were utilized to find least-cost patterns of waste discharges which would produce specified DO improvement profiles throughout the channel. An equitable tax and bounty system was developed to compensate for cost inequities arising from the least-cost solutions and to allocate the resulting savings among waste dischargers. (2 maps, 4 chart, 11 graphs, 1 diagram)

SURFACE WATER MODELS (Continued)

35. TITLE: A Water Management Model Using Earth Resources Satellites  
 AUTHOR: Allan H. Muir  
 SOURCE: Earth Satellite Corp., Washington, D. C., Interdisciplinary Applications in Proceedings of the Princeton Univ. of Conf. on Aerospace Methods for Revealing and Evaluating Earth Resources  
 ABSTRACT: This paper describes a systems analysis study that defined a complex and stringent set of requirements for an earth resources information system using satellite-based remote sensors, developed a concept for a satellite-assisted information system to meet these requirements that appears to be technically feasible for the mid-1970's, and evaluated the costs and benefits of deploying such a satellite system operationally. Throughout the study, the analysis was oriented toward the practical application of the information from an operational remote-sensing satellite system to critical management decisions that could benefit from repetitive, large-area coverage. The analytical framework was provided by developing a "user-decision model," which permitted the information requirements, system concept, and cost-benefit analysis to be generated in cooperation with identified users of a satellite-assisted information system. It is believed that the study demonstrates that:
- (1) substantial benefits can be realized from a satellite system capability such as that conceptualized in the study; and
  - (2) the methodology developed in this study is applicable and appropriate to analyzing other major areas of information needs for earth resources management.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

36. TITLE: Analytical Hydrography in Watershed Engineering Bibliographies and Abstracts  
 AUTHOR: U. S. Department of Agriculture, Hydrograph Laboratory  
 SOURCE: USDA Hydrograph Laboratory, Room 139, Soils Building Plant Industry Station, Beltsville, Maryland 20705  
 ABSTRACT: The report contains abstracts of publications of the USDA Hydrograph Laboratory under five subject matter headings; (1) Meteorology and Climatology (2) Hydrodynamics (3) Soils and Vegetation (4) Hydrogeology (5) Systems Analysis

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SURFACE WATER MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

37. TITLE: Survey of Programs for Water Surface Profiles  
 AUTHOR: Bill S. Eichert  
 SOURCE: Journal of Hydraulics Division, ASCE,  
 Vol. 96, No. HY2, Feb. 1970  
 ABSTRACT: This is an excellent paper in which the author compares in detail six flow profile programs developed by five federal agencies and one state (Iowa) agency. Before making this comparison, Eichert discusses the benefits and problems associated with the use of programs from other organizations. In connection with the comparison of programs, he comments on the overall analysis of flow profiles in natural channels, including types of flow, type and subdivision of natural channels, description of the cross section, critical depth computation, non-uniform velocity distribution, roughness description, and bridge losses.

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38. TITLE: A Problem Oriented Computer Language for Hydrologic Analysis  
 AUTHOR: Dr. B. M. Harley  
 SOURCE: Marine Resources Reference Center, MIT Sea Grant Program, Report No. SG-72033, Cambridge, Mass. 02139  
 ABSTRACT: Development and implementation of a problem-oriented computer language for use in the modeling of river networks. Selection and investigation of strategies for the choice of the "best" parameters for use in the modeling of flood wave dynamics.

39. TITLE: Runoff Models for Urban Drainage Control  
 AUTHOR: Dr. J. C. Schaake  
 SOURCE: Marine Resources Reference Center, MIT Sea Grant Program, Report No. SG-72034, Cambridge, Mass. 02139  
 ABSTRACT: Mathematical models of the stochastic relationship between rainfall and response characteristics of urban catchments. Preliminary systems analysis models will be constructed to identify the important response characteristics. Synthetic runoff hydrographs will be studied and stochastic relationships determined. Important statistical properties of systems response and the parameters of the rainfall and runoff models will be devised

SURFACE WATER MODELS (Continued)

40. TITLE: Mathematical Methodology in Hydrology  
AUTHOR: C. C. Kisiel  
SOURCE: Vol I, Proceedings of the First International Seminar  
for Hydrology Professors, July 1969, University of  
Illinois at Urbana
41. TITLE: Mathematical Model for Dissolved Oxygen  
AUTHOR: R. V. Thomann  
SOURCE: Journal of the Sanitary Engineering Division, ASCE,  
Vol 84, No. SA5, Oct 1963, pp 1-30.
42. TITLE: Time Varying Dissolved-Oxygen Model  
AUTHOR: G. D. Pence, J. M. Jeglic, and R. B. Thomann  
SOURCE: Proc., ASCE, Vol 94, No. SA2, April 1968, pp 381-402

## APPENDIX F

### COASTAL PROCESS MODELS

1. TITLE: Computer Simulation Model of Coastal Processes in Eastern Lake Michigan
- AUTHOR: W. T. Fox and R. A. Davis
- SOURCE: Technical Report No. 5, December 15, 1971 of ONR Task No. 388-092/10-18-68 (414) Office of Naval Research, Geography Branch, Washington D.C.
- ABSTRACT: A computer simulation model is used to study the relationships among barometric pressure, wind, waves, longshore currents beach erosion and bar migration on the eastern shore of Lake Michigan. Harmonic trend analysis with a single Fourier series is used to represent the major trends in weather and wave parameters. In the simulation model, barometric pressure is plotted as a function of time and longshore current velocity is computed as the first derivative of barometric pressure. Breaker height closely approximates a modified form of the second derivative of barometric pressure.
- Daily profiles provide data for nearshore topographic maps. For the simulation model, the nearshore area is broken down into components including beach, foreshore, plunge zone, trough and bar. A gently sloping linear plus quadratic surface is used to represent the barless topography in the nearshore area. Bars and troughs generated by normal and inverted normal curves are superimposed on the linear plus quadratic surface.
- Wave and longshore current energies are computed for storm cycles and post-storm recovery periods. Bar distance is computed as a function of wave energy and bottom slope. Bar migration is a function of longshore current energy. Variations in the position of the plunge zone and nearshore bar along the shore are simulated using a sine function. Simulated maps are produced for each storm cycle and post-storm recovery period.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

2. TITLE: Monitoring Changing Geologic Features Along the Texas Gulf Coast
- AUTHOR: Dr. Ralph E. Hunter
- SOURCE: U. S. Geological Survey  
Corpus Christi, Texas 78411

## COASTAL PROCESS MODELS (Continued)

**SUMMARY:** ERTS imagery will be used in a study of the sources, movement, and deposition of suspended particulate matter in Texas coastal waters and the adjacent Gulf of Mexico. The imagery will provide repetitive, broad, synoptic coverage showing the distribution of turbid water masses. Supplementary imagery obtained by aircraft will be used to measure short-term rates and directions of movement of the water masses and to observe details of turbidity distribution too small to be visible on the ERTS imagery. Release of drift objects will provide further data on water movement. Shipboard measurements of temperatures, salinity, and turbidity through the water column will provide water-truth data for use in the interpretation of the imagery.

Besides defining the paths of suspended sediment movement, a matter of geologic interest, the study will furnish information applicable to studies of physical oceanography, marine biology, and water-borne pollutants.

To the extent that the resolution of the ERTS system permits, the imagery will also be used in studies of shoreline changes and coastal dune movement.

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3. **TITLE:** Storm Surge on the Open Coast: Fundamentals and Simplified Prediction

**AUTHOR:** B. R. Bodine

**SOURCE:** Report No. AD-728-128, National Technical Information Service, Springfield, Virginia

**ABSTRACT:** Open-coast storm-surge computations are of value in planning and constructing engineering works in coastal regions. A quasi-two-dimensional numerical model for such computations is discussed from the standpoint of the model's underlying assumptions, range of validity, calibration, and application. When using simple numerical schemes of this sort, it is possible to make computations manually, although electronic digital calculations are generally preferred.

Elementary aspects of hurricanes and the physical factors governing storm generation processes are discussed. To display the principle characteristics of the model from a physical as well as a mathematical point of view, the basic hydrodynamic equations are given, together with the assumptions generally taken in their development. The equations consistent with the model described here are reduced forms of the basic equations in which several terms have been neglected. These omissions are indicated, and their effects on the resulting numerical scheme are discussed.

# COASTAL PROCESS MODELS (Continued)

The use of design hurricanes for engineering studies is treated. Effects of astronomical tide, initial water level, and atmospheric-pressure setup are considered.

An open-coast storm-surge problem is solved for the Chesapeake Bay Entrance near Norfolk, Virginia. Calculations are made both by computer and manually. The computer program used is listed.

## 4. TITLE: Study on Sand Movement by Wind

AUTHOR: R. Kawamura

SOURCE: Report No. N72-21359, NTIS, Springfield, Virginia 22151

ABSTRACT: Sand movement by wind is studied in detail in this paper. The effect of wind turbulence on sand particles is neglected by taking into account their susceptibility in the natural wind. Sand particles move downstream with bouncing motions near the sand surface and in the stationary state they gain on an average as much momenta from the wind as they lose at the moment of collision on the sand surface. From this, the relation between the rate of sand flow quantity and the friction velocity of the wind is derived. The statistical treatments of the phenomena make it possible for us to calculate the vertical distributions of density of sand particles and quantity of sand flow.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

## 5. TITLE: Directory of M.I.T. Research Projects related to Marine Resources, Ocean Utilization and Coastal Zone Development

AUTHOR: B. Passero and D. A. Horn

SOURCE: Marine Resources Reference Center  
M.I.T. Sea Grant Project Office  
Report No. MITSG 72-10, May 15, 1972  
Cambridge, Mass. 02139

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## 6. TITLE: A Time Series from the Beach Environment-II

AUTHOR: W. Harrison and L. E. Fausak

SOURCE: Data Report No. 7, December, 1970. Task No. NR 388-097, Virginia Institute of Marine Science, Gloucester Point, Virginia

## COASTAL PROCESS MODEL (Continued)

**ABSTRACT:**Intensive sampling of beach variables was undertaken during a 30-day period in August and September, 1969, at Virginia Beach, Virginia. The purpose was to investigate the water table of a marine beach and to clarify the interaction of the water table and several process variables of the beach-ocean-atmosphere system.

This report describes the methods of measurement and tabulates the values obtained for the following variables: breaker height, breaker period, trough-to-bottom depth in front of a breaking wave, breaker steepness, breaker power, position of the limit of swash run-up, position of the outcrop of the water table on the foreshore, slope of the foreshore, water table elevations in each of 13 wells, beach elevations, barometric pressure, rainfall, and still-water level.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

7. **TITLE:** Coastal Zone Management

**AUTHOR:** J.W. Devanney

**SOURCE:** Marine Resources Reference Center, M.I.T. Sea Grant Program, Report No. SG-72040, Cambridge, Mass. 02139

**ABSTRACT:**Research into the application of concepts of economic efficiency to the development and control of the coastal zone.

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## APPENDIX G

### ESTUARY MODELS

1. TITLE: Galveston Bay Project, Water Quality Modeling and Data Management, Phase II Technical Progress Report, July 1971

AUTHOR: W. H. Espey, et al, TRACOR

SOURCE: TRACOR Project 002-070, Document No. T70-AV7636-U  
TRACOR, 6500 Tracor Lane, Austin, Texas 78721

SUMMARY: Briefly summarized, the status of the Phase II effort is as follows:

- a) An analysis of Galveston Bay water quality data and supporting studies has been accomplished in support of the modeling effort.
- b) An efficient and flexible data management system has been made operational to accomodate and process the data accumulated by the GBP.
- c) A hydraulic model has been developed and verified for computing water movements for various tidal stages and velocities.
- d) A steady-state salinity model has been developed and verified for the bay. This model forms the basis for the mass transport model which is used in the various water quality models (with appropriate modifications).
- e) A steady-state one-dimensional BOD<sub>5</sub>/DO model for the upper Houston Ship Channel has been developed and verified; and a one-dimensional dynamic model has also been developed for this channel region.
- f) A one-dimensional, steady-state BOD<sub>5</sub>/DO model for the upper channel has been developed and verified for anaerobic conditions.
- g) Two-dimensional, steady-state BOD<sub>5</sub> and DO models for Galveston Bay system, including the Upper Ship Channel and a 50-mile section of the Trinity River, have been developed and limited verification has been obtained. Additional verification will be provided in the model refinement and operation effort of Phase III.
- h) A two-dimensional, dynamic temperature model describing thermal interactions in Galveston Bay, has been developed and verified.
- i) TRACOR began the development of a steady-state, two-dimensional coliform model for Galveston Bay, but considerable development remains to be done.
- j) Employing the steady-state, two-dimensional mass transport model, the distribution of algal toxicity growth factors (Copeland and Fruh [1]), has been successfully predicted for Galveston Bay.

ESTUARY MODELS (Continued)

- k) Two optimization models have been developed and successfully applied to the Upper Houston Ship Channel. These will be used further in conjunction with the hydraulic and water quality models in making the water quality trade-offs in the selection among various engineering alternatives.

2. TITLE: Mathematical Programming for Regional Water Quality Management  
AUTHOR: Graduate School of Business, University of California, Los Angeles, California  
SOURCE: Report No. 16110 FPX 08/70, Federal Water Quality Administration, Department of the Interior  
ABSTRACT: This report is an application of a non-linear programming algorithm to the problem of optimal water quality control in an estuary. The mathematical model that was developed gives the solution to the general mixed case of at-source treatment, regional treatment plants, and by-pass piping. The non-linear algorithm is developed in considerable detail and a sample problem is worked out. Detailed results are presented for a pilot problem to illustrate the method of solution. Actual data from the Delaware Estuary is used to solve a large scale problem and the solution is given. The results indicate that a regional treatment system for the Delaware Estuary is superior, in terms, of total cost, to other proposed schemes. This report was submitted in fulfillment of Grant No. 16110 FPX between the Federal Water Quality Administration and the University of California, Los Angeles, directed by Dr. Glenn W. Graves, assisted by Andrew B. Whinston and Gordon B. Hatfield.
3. TITLE: Investigation and Prediction of Dispersion of Pollutants in the Sea with Hydrodynamical Numerical (HN) Models  
AUTHOR: P. M. Wolff, et al; Fleet Numerical Weather Central, Monterey, California,  
SOURCE: FAO paper E-46, FAO Techn. Conf. on Marine Pollution, Dec. 9-18, 1970, Rome, research report  
ABSTRACT: Experimental investigation of transport and diffusion of pollutants in estuaries and coastal waters is expensive and time-consuming. However, by using large computers, Hydrodynamical Numerical models can be applied to pollution problems at any location where depth distribution, boundary conditions (tides, fresh-water inflow, wind and pollution source) is specified. The basic hydrodynamical formulae, the finite difference form of W. Hansen and the computer program are given for computation of synoptic distribution and behavior of currents, and diffusion in estuaries and coastal waters. Some special boundary problems and their treatment are described.



# ESTUARY MODELS (Continued)

4. TITLE: Mathematical Modeling of Estuarine Processes

AUTHOR: Arnason, G.

ABSTRACT: The subject is presented in the context of man and his natural environment. The mathematical model can be applied to the simulation of physical processes as well as the reproduction of known chemical and biological processes that take place in an estuary and the intricate interaction between physical and biochemical processes. A schematic diagram identifies the main conceptual building blocks in a rather comprehensive model which is capable of predicting water height, circulation, salinity, transport of waste material, and some important biological processes.

\* \* \* \* \* NON-MODEL \* \* \* \* \*

5. TITLE: Estuarine Modeling: An Assessment

AUTHOR: Edited by G. H. Ward and W. H. Espey, TRACOR, Inc.

SOURCE: TRACOR, Inc., 6500 Tracor Lane, Austin, Texas 78721

ABSTRACT: This report constitutes a technical review and critical appraisal of present techniques of water quality modeling as applied to estuaries. Various aspects of estuarine modeling are treated by a selection of scientists and engineers eminent in the field, and these essays are supplemented by discussions from technical conferences held during the course of the report's preparation. Topics discussed include one-, two-, and three-dimensional mathematical models for estuarine hydrodynamics, water quality models of chemical and biological constituents including DO, BOD, nitrogen forms, phytoplankton and general coupled reactants, models of estuarine temperature structure with special attention given the modeling of thermal discharges, and the principles and applicability of physical models in estuarine analysis. Also included is a review of solution techniques, viz, analog, digital and hybrid with a detailed discussion of finite-difference methods, a brief survey of estuarine biota and present biological modeling activities, and a collection of case studies reviewing several past estuarine modeling projects. Conclusions about the existing state of the art of estuarine modeling and recommendations for future research by EPA are advanced throughout the report and are summarized in the final chapter.

\* \* \* \* \*

ESTUARY MODELS (Continued)

6. TITLE: Supermodel  
AUTHOR: Joann Temple Dennett,  
SOURCE: NOAA, Jan. 1972, v2, n1, p32 (3) news feature  
ABSTRACT: A computer model devised by Environmental Research Laboratories' Geophysical Fluid Dynamics Lab (GFDL) combines mathematical models of the oceans and atmosphere to define the interrelationships among oceanic and atmospheric conditions, and analyze the global environment. The model calculates and examines such factors as: shoreline and ocean bottom characteristics, temperature changes, salinity rates, density, sea ice movements, and additional heat budget factors. Major oceanic features are reproduced on a grid system. The model is applicable in predicting environmental conditions and distinguishing among problems that affect the environment. (2 maps, 1 photo, 2 diagrams)
7. TITLE: A Mathematical Model for Evaluating the Potential of Desalting  
AUTHOR: T. Rothermel, et al, Arthur D. Little, Inc., Cambridge, Mass.  
SOURCE: Water Resources Bulletin, Aug. 1971, v7, n4, p867 (10) technical report  
ABSTRACT: Dynamic simulation model developed to translate relevant factors of water supply and demand into a forecast of desalting potential is reported. The model projects the needs for desalting in 20 hydrologic regions of the US. Model performance has thus far been demonstrated by the development of a forecast and a battery of related sensitivity tests. Current results indicate the following potential desalting capacities: 225MGD in 1980; 2,250 MGD in 2000 and 7,000 MGD in 2020. Significant improvements in desalting economics promises to increase these potentials by a factor of four or five by 2020. Model inputs and results are continuing to be refined.
8. TITLE: A Computer Simulation Program for Optimizing Conjunctive Operation of Desalting Plants  
AUTHOR: Wesley Blood, et al, Utah State University  
SOURCE: Water Resources Bulletin, Aug. 1971, v7, n4, p785 (17) technical report  
ABSTRACT: A computer program that can help water planners find an optimal operating rule for desalination operations is described. Desalting plants can firm up erratic natural supplies when properly operated in conjunction with existing water reservoir systems.

# ESTUARY MODELS (Continued)

Since the natural inflow is variable, the choice of when to run the desalting plant is difficult. If the plant is turned on too soon, a shortage may result; or if the plant runs too long, costly water may be wasted. Criteria for defining the firm water yield of the system are first defined. The logic of the program is then described. The program, written in FORTRAN IV, simulates operation of the given size reservoir-desalting plant system under control of various operating rules and selects the optimal rule as the one which produces the required firm yield at the least unit cost. The optimal plant size and staging of construction can also be studied. Applications of the Operating Rule program to water systems in California, Utah and New York are described. The studies indicate that, compared with base load operation, substantial savings are possible if optimum intermittent conjunctive operation of the desalting plant is followed. (12 charts)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

9. TITLE: Directory of M.I.T. Research Projects Related to Marine Resources, Ocean Utilization and Coastal Zone Development

AUTHOR: B. Passero and D. A. Horn

SOURCE: Marine Resources Reference Center  
M.I.T. Sea Grant Project Office  
Report No. MITSG 72-10, May 15, 1972  
Cambridge, Massachusetts 02139

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10. TITLE: A Study of the Salt Balance in a Coastal Plain Estuary

AUTHOR: Pritchard, D. W.

SOURCE: J. of Marine Res. 13(1):133-144

ABSTRACT: Author uses observations of salinity and current velocity to develop a model for the salt balance in an estuary. The analysis showed that the horizontal advective flux and the vertical non-advective flux of salt are the most important in maintaining the salt balance. The vertical advective flux is still significant and the effect of the horizontal nonadvective flux is small.

11. TITLE: A Mathematical Model of Regional Variations in Plankton.

AUTHOR: Riley, G. A.

SOURCE: Limnol. Oceanog. 10(Suppl.):R202-R215

ESTUARY MODELS (Continued)

ABSTRACT: The relationships of phytoplankton, zooplankton, and a limiting nutrient (phosphate) are examined in a simple two-layered model. The model is applied to assumed steady-state conditions that occur in summer so that wide geographical areas can be treated. For any given array of environmental factors, steady state concentrations of the plankton organisms and phosphate can be found. Basic environmental variables used are: 1) phosphate concentration, 2) rate of mixing between the layers, and 3) temperature.

12. TITLE: Heat Transfer Analysis for a Typical Estuarine Lake,  
AUTHOR: Simon Hacker and R. W. Pike, Louisiana State University,  
Baton Rouge, Louisiana  
SOURCE: Paper presented at AIChE 68th Nat'l. Meeting, Houston,  
Texas, Feb. 28-Mar 4, 1971, research report  
ABSTRACT: The general energy equation is applied to a typical estuarine lake in Gulf area. Special boundary conditions are evaluated for the air-water and water-bottom interfaces and used with the special equations to form a heat transfer model. Results are given for diurnal variations in the temperature distribution and the transfer rates at the two interfaces, and are compared with experimental data.
13. TITLE: Mathematical Models for Predicting the Transport of Radionuclides in a Marine Environment  
AUTHOR: G. S. Bloom and G. E. Raines  
SOURCE: Battelle Memorial Inst., Columbus Laboratories, and Bioscience, June 15, 1971, v21, n12, p691 (5) technical feature  
ABSTRACT: A mathematical model to describe the transport of radionuclides from ground water and fallout sources into and within a marine environment is described. Based on this model, expressions are derived for estimating the potential internal radiation dose to man due to his consumption of fish from a contaminated marine environment. These expressions give conservatively high dose estimates which can be compared with radiation protection guides to determine the necessity, if any, of radiological safety measures. (1 chart, 4 diagrams)

ESTUARY MODELS (Continued)

\* \* \* \* \* NON-MODEL \* \* \* \* \*

14. TITLE: Mathematical Models for Estuaries, Selected Bibliography  
AUTHOR: Carl J. Huval  
SOURCE: Department of the Army  
Waterways Experiment Station,  
Corps of Engineers  
P. O. Box 631  
Vicksburg, Mississippi 39180

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15. TITLE: Mathematical Programming for Regional Water Quality Management  
AUTHOR: Glenn W. Graves, et al, University of California, Los Angeles  
SOURCE: Water Resources Research, Apr. 1972, v8, n2, p273 (17)  
research report  
ABSTRACT: Application of mathematical programming in establishing optimal water quality control in an estuary allows for the possibilities of at-source treatment, regional treatment plants, and by-pass piping. Actual data from the Delaware Estuary are used to solve a large scale problem. Results indicate that a regional treatment system for the Delaware Estuary is superior, in terms of total cost, to other proposed schemes. (12 charts, 5 graphs, 8 diagrams)

16. TITLE: The Relative Importance of Freshwater Input, Temperature and Tidal Range in Determining Levels of Dissolved Oxygen in a Polluted Estuary  
AUTHOR: David W. Mackay and John Gilligan, Clyde River Purification Board, U.K.  
SOURCE: Water Research, 1972, v6, p183 (8) research report  
ABSTRACT: Individual and combined effects of freshwater input, temperature, and tidal range on dissolved oxygen levels in a highly polluted estuary (Clyde River) are established. The construction of a mathematical model for prediction of dissolved oxygen at each of 13 stations spaced at intervals along 38 km of the estuary is described. (1 map, 4 charts)

17. TITLE: Stochastic Modeling for Water Quality Management  
AUTHOR: Stochastics, Inc., Blacksburg, Virginia  
SOURCE: Contract # 6090 DUH 02/71, EPA Water Quality Office, USGPO. Water Pollution Control Research Series, Feb. 1971 (395) research report.

ESTUARY MODELS (Continued)

ABSTRACT: Previously defined stochastic models were extended and verified with data obtained from the Ohio River and the Potomac Estuary. Fully realized test objectives included: modifying the model to accept variable or random input loads, adapting the estuary model to segmented estuaries, verifying the adopted model with EPA Water Quality Office data, and devising a method to estimate and predict the stochastic parameter (numerous charts, graphs, and diagrams).

18. TITLE: Real-Time Model for Estuarine Water Quality Prediction

AUTHOR: Dr. D. Harleman

SOURCE: Marine Resources Reference Center  
M.I.T. Sea Grant Program  
Report No. S6-72023  
Cambridge, Mass. 02139

ABSTRACT: Numerical solution by finite difference techniques of the longitudinal distribution of water quality parameters in an estuary. The mathematical model includes non-linear effects such as variable area, variable dispersion and the instantaneous tidal velocity.

19. TITLE: Water Quality Model for a Network of Estuarine Channels

AUTHOR: Dr. A. Ippen

SOURCE: Marine Resources Reference Center  
M.I.T. Sea Grant Program  
Report No. S6-72016  
Cambridge, Mass. 02139

ABSTRACT: An estuary consisting of channels and junctions is modeled mathematically by a network of one-dimensional channels. A finite element model is used for solution of the equations of motion and mass transfer with tidal advection and dispersion included for each branch of the network. These equations are solved to provide time-dependent concentration distributions for non-conservative water quality parameters.

20. TITLE: A Two-Dimensional Model for Salinity Intrusion in Estuaries

AUTHOR: Dr. A. Ippen

SOURCE: Marine Resources Reference Center  
M.I.T. Sea Grant Program  
Report No. S6-72018  
Cambridge, Mass. 02139

ESTUARY MODELS (Continued)

ABSTRACT: Analytical methods to describe the two-dimensional salinity distribution in an estuary which is homogenous laterally, but non-homogenous vertically. The initial phase is concerned with time-averages of salinity and velocity over a tidal period. The objective is to provide a better understanding of salinity and sediment transport processes in estuaries.

21.TITLE: Modeling of the Nitrogen and Algal Cycles in Estuaries

AUTHOR: Thomann, R. V.: O'Connor, D. J.: DiToro, D.M.

SOURCE: 5th International Water Pollution Research Conference  
San Francisco, California

ABSTRACT: Describes model for physical and ecological kinetics of nitrogen. Model is compared to data from two estuaries.

22.TITLE: Model Studies of Salt Water Intrusion

AUTHOR: Abdel-Aziz I. Kashef, Prof. C.E. North Carolina State University

SOURCE: Water Resources Bulletin, Dec. 1970, v6, n6, p 944

ABSTRACT: The use of viscous flow models (Hele-Shaw) to verify certain theories in ground water flow systems, and their connection with salt-water intrusion problems are examined. Related applications, such as gravity flow systems, problems in oil fields, and other flow models are considered (Charts, Diagrams).

23.TITLE: Models Predict Environment

SOURCE: Sea Frontiers, Nov-Dec 1970, v16, n6, p352 (5) technical feature

ABSTRACT: Waterways Experiment Station, operated by the Army Corps of Engineers in Miss., makes "preventive" ecological insight possible by using hydraulic models. Quantitative determination of changes in tidal and salinity conditions of estuaries can be predicted, as well as overall effect of proposed projects on flushing characteristics and sediment deposition.

24.TITLE: Mathematical Modeling of Estuarial Systems

AUTHOR: Orlob, Gerald T.

SOURCE: Proceedings, International Symposium on Mathematical Modeling Techniques in Water Resources Systems, May 1972

ESTUARY MODELS (Continued)

25. TITLE: A Water-Quality Simulation Model for Well-Mixed Estuaries and Coastal Seas: Volume I, Principles of Computation  
AUTHOR: Leendertse, J. J.  
SOURCE: The Rand Corporation, Memorandum RM-6230-RC, February 1970
26. TITLE: Mathematical Modeling of Water Quality in Estuarine Systems  
AUTHOR: Orlob, G. T., Shubinski, R. P., and Feigner, K. D.  
SOURCE: Proceedings of the National Symposium on Estuarine Pollution, Stanford University, August 1967
27. TITLE: Documentation Report: FWQA Dynamic Estuary Model  
AUTHOR: Feigner, K. D. and Harris, H. S.  
SOURCE: U.S. Department of the Interior, Federal Water Quality Administration, July 1970
28. TITLE: A Mathematical Model of the Effect of a Tidal Barrier on Siltation in an Estuary,  
AUTHOR: Owen, M. V., and Odd, N. V. M.  
SOURCE: International Conference on the Utilization of Tidal Power, Halifax, Nova Scotia, May 1970
29. TITLE: A Numerical Model of the Salinity Distribution in Upper Chesapeake Bay  
AUTHOR: Boicourt, W.  
SOURCE: Chesapeake Bay Institute, John Hopkins University, Technical Report No. 54, May 1969
30. TITLE: Simulation of Tidal Hydrodynamics in Shallow Irregular Estuaries  
AUTHOR: Masch, F. D., Shankar, N. J., Jeffrey, M., Brandes, R. J. and White, W. A.  
SOURCE: Hydraulic Engineering Laboratory, The University of Texas at Austin, Technical Report HYD 12-6901, February 1969



ESTUARY MODELS (Continued)

31. TITLE: Mathematical Model Study of the Propagation of Tides in the St. Lawrence River and Estuary  
AUTHOR: Kamphuis, J. W.  
SOURCE: Publication of the National Research Council, Canada MH-105, August 1968
32. TITLE: Numerical Modeling of Hydro-Mechanics of Bay Systems  
AUTHOR: Verma, A. P. and Dean, R. G.  
SOURCE: Proceedings, Civil Engineering in the Ocean II, Miami, 1969